Application Report
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ISM-Band and Short Range Device Regulatory Compliance Overview

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ABSTRACT

This application report covers the requirements for regulatory compliance in United States and Europe. The FCC and ETSI regulations for ISM bands or SRD are covered in detail for both transmitters and receivers. A brief explanation of the test procedures is also included in this report.

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1 Introduction

Texas Instruments' low-power RF devices make it easier to build wireless links for remote control, metering, and sensing applications. In most cases, they are used inside unlicensed, or license-free, wireless products. Unlicensed means only that the user of these products does not need an individual license from the telecommunication regulatory authorities. Unlicensed does not mean unregulated; the wireless product itself usually will need to meet strict regulations and be certified by the appropriate regulatory authorities.

This application note is a summary of the regulations and procedures in the United States and the European Union for unlicensed RF products operating in the frequency range between 300 MHz and 2.5 GHz. Such products are often referred to as ISM-band products in the US and SRD products in the EU. (ISM is short for the Industrial, Scientific, and Medical frequency bands, and SRD is an abbreviation of Short-Range Devices.) Both the US and EU regulatory agencies place limitations on the operating frequencies, output power, spurious emissions, modulation methods, and transmit duty cycles, among other things. The limitations and requirements in the US are covered in section 2, while those for the EU are covered in section 3.

1.1 Power Emissions Conversion

Before discussing the details of the regulations, it needs to be noted that there are several accepted means of describing one of the most important regulated parameters of an RF device: its radiated emissions. All unlicensed devices have some limitation on the amount of output power, or radiated energy, they can produce. What differs among the various regulatory agencies is the means of describing this limit. Radiated energy can be described in terms of: the electrical field strength (E) measured at some distance from the radiator, the effective isotropic radiated power (EIRP) or the effective radiated power (ERP).

The electrical field strength (E) is perhaps the most precise way of describing the actual RF energy present at a point in space that a receiving antenna could use. Since the RF energy decreases with increasing distance from the transmitting antenna, the regulatory limits based on electrical field strength are specified at a specific distance from the transmitting antenna.

While the electrical field strength may be precise, it is often not as useful from a design perspective as the effective isotropic radiated power, or EIRP. The EIRP is the power that would have to be supplied to an ideal antenna that radiates uniformly in all directions in order to get the same electrical field strength that the device under test produces at the same distance. (Such an antenna is called an **isotropic radiator**.) Given a distance r from the transmitting antenna, the EIRP can be calculated from E using the following formula:

$$\text{EIRP} = 10\log\left(\frac{4\pi \times E^2 \times r^2}{0.377\ [V^2]}\right) = 10\log\left(\frac{E^2 \times r^2}{0.030\ [V^2]}\right) \quad (1)$$

where the EIRP is in dBm and V is the unit of measurement.

The effective radiated power, ERP, is similar to the EIRP. It is the power that would have to be supplied to a **half-wave dipole** to get the same electrical field strength that the device under test produces at the same distance. A half-wave dipole is more representative of realistic simple antennas than an isotropic radiator. Since a half-wave dipole radiates more energy in some directions and less in others, it is said to have antenna gain in the direction of the most energy. The amount of antenna gain is usually expressed in dB relative to an isotropic radiator, or dBi. The maximum gain of a half-wave dipole is 2.15 dBi. Thus, in the direction of maximum gain, the amount of power required to produce the same electric field is less with a half-wave dipole than it is with an isotropic radiator. If both the ERP and the EIRP are expressed using a logarithmic scale, such as dBm, it holds that:

ERP = EIRP – 2.15 dB

If one of the three parameters EIRP, ERP, or E at a distance r is given, the other two can be calculated.

See section 3 of the Antenna applications report, SWRA046, to relate transmit power to communication distance.

2 Regulations in the United States

In the US, the Federal Communications Commission (FCC) regulates the use of frequencies for wireless communication. The FCC rules and regulations are codified in Title 47 of the Code of Federal Regulations (CFR). Part 15 of this code applies to radio frequency devices operating at unlicensed frequencies and is often colloquially referred to as *FCC Part 15*. Within Part 15 are several sections. In the discussion below, the term *section 15.xxx* refers to a specific section within FCC Part 15. The latest version of the FCC rules can be found at the web site: www.fcc.gov.

After a discussion on the general limits of unlicensed devices in section 2.1 of this document, the regulations for control and periodic applications are summarized in section 2.2. For higher power operation with less application restrictions, the industrial, scientific, and medical, or ISM, bands near 900 MHz and 2.4 GHz can be used. The regulations governing those bands are described in sections 2.3 and 2.4. Finally, a brief description of the testing and certification procedures is provided in section 2.5.

2.1 Spurious Emission Limits and Restricted Frequency Bands

The regulations in Part 15 begin by specifying general limitations on RF emissions and defining restricted frequency bands. For the regulations limiting RF emissions, the FCC distinguishes between intentional, unintentional and incidental radiators.

Intentional radiators are devices that intentionally emit RF energy, such as transmitters.

Unintentional radiators are devices that intentionally generate RF energy for use within the device or a cable system only but not for the purpose of radiation. Examples for unintentional radiators are: computer motherboards and receivers with local oscillators.

Incidental radiators are devices that are not designed to generate RF energy at all, but for which RF radiation may occur as an unwanted side effect. Examples of incidental radiators are dc motors and mechanical switches.

The general limits for the emission of intentional or unintentional radiators are given in FCC section 15.209 in terms of the allowed electrical field strength measured at a distance of three meters. The spurious emission limits for all frequencies above 30 MHz as well as the corresponding EIRP in dBm are listed in Table 1. Any emission above these limits must be specifically allowed by other sections in Part 15. These allowed exceptions form the basis of most low power wireless devices in the US.

Table 1. Spurious Emission Limits According to Section 15.209

Frequency	Electrical Field Strength	Corresponding EIRP
30 ... 88 MHz	100 µV/m	– 55.2 dBm
88 ... 216 MHz	150 µV/m	– 51.7 dBm
216 ... 960 MHz	200 µV/m	–49.2 dBm
> 960 MHz	500 µV/m	–41.2 dBm

In addition to the emission limits in Table 1, there are restricted frequency ranges, or bands, defined in section 15.205, in which only spurious frequencies may be produced. That is, the fundamental frequency of an intentional radiator cannot fall within one of these restricted frequency bands even if the transmit power is less than the limit in Table 1. The restricted frequencies from 300 MHz to 10 GHz are listed in Table 2.

Table 2. Restricted Frequency Bands

MHz	MHz	GHz
322 – 335.4	1718.8 – 1722.2	3.6 – 4.4
399.9 – 410	2200 – 2300	4.5 – 5.15
608 – 614	2310 – 2390	5.35 – 5.64
960 – 1240	2483.5 – 2500	7.25 – 7.75
1300 – 1427	2655 – 2900	8.025 – 8.5

Table 2. Restricted Frequency Bands (continued)

MHz	MHz	GHz
1435 – 1626.5	3260 – 3267	9 – 9.2
1645.5 – 1646.5	3332 – 3339	9.3 – 9.5
1660 – 1710	3345.8 – 3358	10.6 – 12.7

Additionally, according to section 15.209, the frequency bands listed in Table 3 can be used by transmitters only if the requirements of section 15.231 are fulfilled; these requirements are discussed in section 2.2 of this document.

Table 3. Restricted Transmit Bands

MHz	MHz
54 – 72	76 – 88
174 – 216	470 – 806

Outside the restricted bands, one can transmit at any frequency as long as the radiated output power is below the spurious emission limits in Table 1. This can be an option if the distance between the transmitter and the receiver is very short.

2.2 Enhanced Emission Limits for Control and Periodic Applications

FCC section 15.231 allows higher transmit power levels under certain conditions in the frequency band of 40.66 MHz to 40.7 MHz and above 70 MHz. These conditions can be grouped into two broad applications types: control applications and other periodic applications. Control applications have more restrictions on the type of application, but have a higher output power allowance. Other periodic applications have less restriction on the application, but lower output power allowance

2.2.1 Control Applications

Control applications must meet the conditions that are listed in FCC paragraph 15.231(a). These conditions are summarized below.

- The transmitter must be used to transmit a simple control signal, like an alarm system, a door opener, or a remote switch. Data may be sent together with the control signal.
- If the transmitter is operated manually, an automatic switch must cease the transmission within five seconds after releasing.
- If the transmission is started automatically, it must not last longer than five seconds.
- Continuous transmissions, voice, video and radio control of toys are not allowed.
- Periodic transmissions at regular predetermined intervals are not allowed. The only exception is integrity testing in security or safety applications. In these cases, the total duration of transmissions for each transmitter must not exceed two seconds per hour.
- Transmitters used to signal a fire, security or safety of life, alarm may operate while the alarm condition exists without time limitations.

If the conditions of paragraph 15.231(a) are fulfilled, the maximum permitted electrical field strength at a distance of three meters increases linearly with frequency from 3750 µV/m at 260 MHz to 12500 µV/m at 470 MHz according to the following equation:

$$E = \left(41.6667 \frac{\mu V}{m \times MHz}\right) \times f - 7083.333 \frac{\mu V}{m} \quad (2)$$

where f is the transmitter center frequency. For all frequencies above 470 MHz, 12500 µV/m at a distance of 3 meters is allowed. The maximum spurious output, such as harmonics of the transmitter, is 20 dB below the limit for the fundamental, unless the spurious output falls in one of the restricted bands listed in Table 2. If the spurious output does fall in a restricted band, it must meet the field strength limits listed in Table 1.

In addition to the application and power limits above, there is an additional condition on the bandwidth of the transmitted channel. If the bandwidth is measured as the frequency span in which the transmitted spectral density is within 20 dB of the maximum spectral density, the bandwidth of data channel must be less than 0.25% of the center frequency for devices operating below 900 MHz. Above 900 MHz, the maximum 20-dB bandwidth of the channel is 0.5% of the center frequency. The bandwidth condition can be met by all Texas Instruments TRF49xx and TRF69xx devices.

2.2.2 Other Periodic Applications

For applications that do not meet the restrictions of paragraph 15.231(a), lower transmit signal levels are given in paragraph 15.231(e). These lower limits apply to any type of periodic data transmission including applications prohibited in paragraph 15.231(a), as long as the duration of one transmission is shorter than 1 second and the silent period between transmissions is at least 30 times the duration of the transmission, or 10 seconds, whichever is greater.

Paragraph 15.231(e) allows the electrical field strength in three meters distance increasing from 1500 µV/m at 260 MHz to 5000 µV/m at 470 MHz according to the equation:

$$E = \left(16.6667 \frac{\mu V}{m \times MHz}\right) \times f - 2833.333 \frac{\mu V}{m} \quad (3)$$

where *f* is the transmitter center frequency. Above 470 MHz, the field strength limit is a constant 5000 µV/m. As with the control applications, all spurious emissions must be 20 dB below the limit for the fundamental signal or below the limits in Table 1, if they fall into restricted bands.

2.2.3 Control and Periodic Application Design Guidelines

For the designer it is important to know the permitted output power of a transmitter. The effective isotropic radiated power, EIRP, can be calculated from the electrical field strength E using the formula in section 1.1 of this document. For the distance r of three meters, as specified in the FCC part 15 regulations considered here, the formula can be simplified to

$$EIRP = 20 \log\left(\frac{E}{\mu V/m}\right) - 95.23 \quad (4)$$

where EIRP is in dBm. The electrical field strength limits and the corresponding EIRP limits at 260 MHz and 470 MHz and above are listed in Table 4. The emissions limits for control and other periodic devices, and the restricted frequency bands, are summarized graphically in Figure 1.

Table 4. Electrical Field Strength and Resulting EIRP Limits According to Paragraph 15.231

Frequency	Paragraph 15.231(a)		Paragraph 15.231(e)	
	Electrical Field Strength in 3 Meters Distance	Resulting EIRP	Electrical Field Strength in 3 Meters Distance	Resulting EIRP
260 MHz	3750 µV/m	–23.75 dBm	1500 µV/m	–31.71 dBm
470 MHz and above	12500 µV/m	–13.3 dBm	5000 µV/m	–21.25 dBm

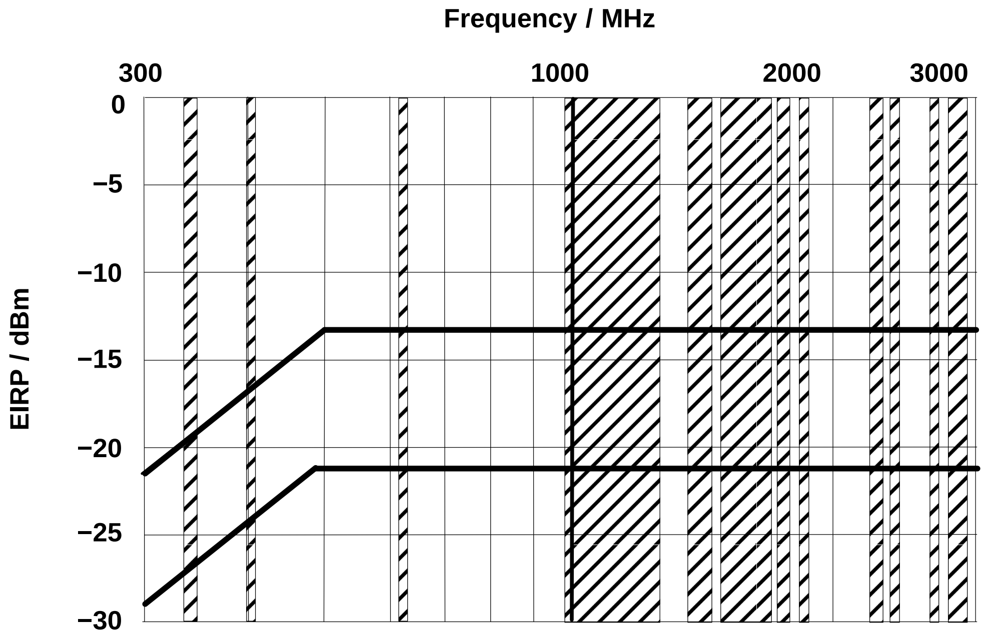

Figure 1. EIRP Limits According to Section 15.231 and Restricted Bands According to 15.205

Depending on the application, it may be possible to transmit at power levels above these prescribed limits. This is allowed by taking advantage of the averaging detector that is used in the certification of control or periodic products operating under FCC section 15.231. Because the averaging window of this detector is 100 ms, if the transmission burst is less than 100 ms, the transmit power can be increased by the ratio of 100 ms to the transmit time, up to a maximum increase of 20 dB. This is described in more detail in section 2.5 in this document.

The design of a control or periodic application can be made easier by choosing the operating frequency wisely. All transmitters generate some level of spurious emissions, especially at the harmonics, or multiples, of the fundamental frequency. These harmonics have to be suppressed, either by output amplifier design or by using filters, to levels that are acceptable under FCC rules. In order to ease the difficulty of the design, it is a good practice to choose fundamental frequencies that don't have harmonics in the restricted bands.

A list of fundamental frequencies between 300 and 900 MHz without harmonics in the restricted bands is provided in Table 5. The right column lists all the fundamental frequencies that have all harmonics up to the fifth harmonic outside the restricted bands. For a slightly more challenging design, but with more frequency choices, the left column lists all the fundamental frequencies that have all harmonics up to the third harmonic outside the restricted bands.

Table 5. List of Frequencies Without Spurs in the Restricted Bands

Up to 3rd Harmonic Considered	Up to 5th Harmonic Considered
300 ... 304 MHz	413.33 ...415 MHz
307 ... 320 MHz	427.5 ... 429.7 MHz
413.33 ... 433.33 MHz	430.55 ... 433.33 MHz
475.67 ... 478.33 MHz	478.0 ... 478.33 MHz
620 ... 650 MHz	620.0 ... 620.88 MHz
713.5 ... 717.5 MHz	625 ... 650 MHz
813.25 ... 822.75 MHz	813.25 ... 815 MHz
823.25 ... 827.83 MHz	823.25 ... 827.83 MHz
855 ... 859.4 MHz	855.0 ... 859.4 MHz
861.1 ... 885 MHz	861.1 ... 870 MHz

2.3 Operation in the 902–928 MHz Band

The frequency band of 902–928 MHz is one of the Industrial, Scientific, and Medical bands in the US, commonly abbreviated as the 915-MHz ISM band. In this band, there are no restrictions to the application or the duty cycle as there were for the control and periodic applications described above. Furthermore, the allowed power output is considerably higher. Because of the lack of restrictions and higher allowed power, this band is very popular for unlicensed short range applications including audio and video transmission. FCC section 15.249 allows 50 mV/m of electrical field strength at 3 meters distance in the frequency band of 902–928 MHz. This corresponds to an EIRP of –1.23 dBm. The harmonics limit is one hundredth of the fundamental level, 500 µV/m, corresponding to an EIRP of –41.23 dBm. Note that this is the same as the spurious emission limit listed in Table 1.

2.3.1 Frequency Hopping Spread Spectrum

Even higher output power can be used if the system employs some form of spread spectrum such as frequency hopping or direct sequence spread spectrum. The reason such allowances are made is that spread spectrum systems are less likely to interfere with other systems than are single frequency transmitters. They also have the advantage in that they are often more immune to interference from other systems. The limitations and qualifications of a spread spectrum transmitter are defined in FCC section 15.247

An application qualifies as a frequency hopping system under section 15.247 if:

- The transmitter pseudo-randomly hops between frequencies that are separated from each other by at least the 20-dB bandwidth of the data channel, but not less than 25 kHz.
- The 20-dB bandwidth of the hopping channel is not larger than 500 kHz.
- If the 20-dB bandwidth of the hopping channel is less than 250 kHz, the system must use at least 50 hopping frequencies. The average time of occupancy at any frequency (dwell time) must not be larger than 0.4 seconds within any 20 second period.
- If the bandwidth of the hopping channel is larger than 250 kHz, the system must use at least 25 hopping frequencies. The average time of occupancy at any frequency must not be larger than 0.4 seconds within any 10 second period.

It is not permitted to synchronize transmitters of different frequency hopping systems to each other. This could lead to a *super system* that occupies individual frequencies for more than the allowed 0.4 seconds in the 10s or 20s period. Notwithstanding this, any system may recognize others in the frequency band and adapt its hop set independently to avoid hopping into an occupied channel.

The output power limits for frequency hopping is one of the few times that the FCC expresses such a limit in units other than the observed electric field strength. As long as the antenna gain is not larger than 6 dBi, the permitted peak transmit power delivered to the antenna is +30 dBm for systems with a 20-dB bandwidth lower than 250 kHz and at least 50 hopping frequencies. For systems with a larger bandwidth but less than 50 hopping frequencies, the peak transmit power is +24 dBm.

If the antenna gain is larger than 6 dBi, the peak transmit power must be reduced by the amount of antenna gain that exceeds 6 dBi. In other words, the maximum EIRP allowed (the peak transmit power plus the isotropic antenna gain), is +36 dBm or +30 dBm depending on the channel bandwidth.

Instead of frequency hopping, spectral spreading can also be accomplished by digital modulation at a high data rate or by direct sequence spread spectrum techniques. If the 6 dB bandwidth of the modulated signal is not less than 500 kHz, section 15.247 permits a maximum peak output power of +30 dBm. If the isotropic antenna gain is larger than 6 dBi, the output power must be reduced accordingly. As an additional limitation, the peak power spectral density conducted to the antenna must not be greater than +8 dBm within any 3 kHz bandwidth. This corresponds to distributing the +30 dBm output power uniformly over the 500-kHz bandwidth.

There are relaxed spurious emission requirements to transmitters that qualify as frequency hopping or spread by digital modulation according to section 15.247: the emission in any 100-kHz bandwidth outside the 902–928 MHz band must only be at least 20 dB below the emission in the 100-kHz bandwidth within the band that contains the highest power. The transmitter does not have to comply with the spurious emission limits specified in Table 1 unless it falls within one of the restricted bands listed in Table 2. Unfortunately, for fundamental signals in the 902–928 MHz band, the 3^{rd}, 4^{th}, and 5^{th} harmonics all fall into restricted bands, causing some design constraints on the output filtering in these systems.

The limits given in FCC sections 15.247 and 15.249 for the 902–928 MHz band are summarized in Table 6.

Table 6. Transmit Power Limits for the 902–928 MHz Band

Transmission Type	Fundamental		Harmonics	
	E at 3m	EIRP	E at 3m	EIRP
Frequency hopping		≥ 50 channels: +36 dBm < 50 channels: +30 dBm	20 dB below the peak in-band emission in any 100-kHz bandwidth	
Digitally spread		+36 dBm		
Other	50 mV/m	–1.23 dBm	500 µV/m	–41.23 dBm

2.4 Operation in the 2.4–2.4835 GHz Band

The 2.4–2.4835 GHz band is another ISM band covered by FCC sections 15.247 and 15.249. For single frequency or other systems that do not qualify as spread spectrum, the same transmit power limits as in the 902–928 MHz band applies. The only difference is that an averaging detector can be used in the 2.4-GHz band allowing a higher peak output power, with the limitation that the peak electrical field strength must not be more than 20 dB above the average value. Thus, similar to the control and periodic applications described above, the transmit strength can be up to 20 dB larger than the limits for continuous signals if the duty cycle is reduced accordingly.

As with the 902–928 MHz band, larger transmit power levels are allowed if the spectrum is spread by frequency hopping or digital modulation. The criteria for a frequency hopping system in the 2.4-GHz ISM band are:

- The transmitter hops pseudo-randomly between at least 15 non-overlapping frequency channels.
- The average time of occupancy at any frequency must not be larger than 0.4 seconds within a time period of 0.4 seconds multiplied by the number of channels

The permitted peak transmit power measured at the antenna input of a frequency hopping system with at least 75 hopping frequencies is +30 dBm. For systems with less than 75 but at least 15 hopping frequencies, a peak transmit power of +21 dBm is allowed. Similar to the 902–928 MHz band, the power has to be reduced if the isotropic antenna gain is larger than 6 dBi. This allows a maximum EIRP of +36 dBm in a system with at least 75 channels or +27 dBm in a system with less than 75 but at least 15 channels.

The criteria and power limits for digitally spread transmitters are same as the 902–928 MHz band.

The limits given in sections 15.247 and 15.249 for the 2.4–2.4835 GHz band are summarized in Table 7.

Table 7. Transmit Power Limits for the 2.4–2.4835 GHz Band

Transmission Type	Fundamental		Harmonics	
	E at 3m	EIRP	E at 3m	EIRP
Frequency hopping		≥ 75 channels: +36 dBm < 75 channels: +30 dBm	20 dB below the peak in-band emission in any 100-kHz bandwidth	
Digitally spread		+36 dBm		
Other	50 mV/m	–0.23 dBm	500 µV/m	–41.23 dBm

The 2.4-GHz band is a worldwide unlicensed band. This is an important advantage compared to the 902–928 MHz band. The 2.4-GHz band also has a wider bandwidth than the 902–928 MHz band which means more available channels. The disadvantages of the 2.4-GHz band are: increased cost and current consumption of the active components, reduced propagation distance for the same power, and increased band congestion due to such systems as Bluetooth and wireless internet.

2.5 Compliance Testing and Certification Process

If a vendor or manufacturer wants to bring an unlicensed wireless transmitter to the US market, they must have the transmitter tested in a laboratory that is authorized by the FCC. After successful completion of testing, the manufacturer applies to the FCC for certification. If the test results are compliant with the regulations of FCC part 15, the FCC will certify the transmitter and issue an FCC identification number for the product. The vendor then must attach a label to each transmitter that contains this FCC identification number.

Receivers do not need a certification, but the vendor has to state in a Declaration of Conformity (DOC) that each device complies with the spurious emission requirements of unintentional radiators according to section 15.209.

All measurements required to prove conformity are conducted, or radiated frequency-selective, power measurements. (In some cases the electrical field strength at a given distance is specified, which is equivalent to a power measurement.) FCC section 15.35 specifies the detector types and bandwidths of the required measuring receivers.

Unless otherwise stated, all measurements below 1 GHz shall be done using a CISPR quasi peak detector. The specifications of this detector can be found in publication 16 of the International Special Committee on Radio Interference (CISPR) of the International Electro-technical Commission (IEC). In general terms, this detector is a peak detector with an attack time of 1 ms and a decay time of 500 ms. The bandwidth of the measuring receiver should be 100 kHz. If specialized equipment is not on hand, a spectrum analyzer with 100 kHz resolution bandwidth and a large video bandwidth setting gives results close to that of a CISPR quasi peak detector.

Above 1 GHz, an averaging detector is used. This detector should have a resolution bandwidth of 1 MHz and average the measurement results over a period of 100 ms. A spectrum analyzer with a resolution bandwidth of 1 MHz and a video bandwidth set to 10 Hz comes close to the averaging receiver specified in section 15.35. In all cases where an averaging detector is specified, an additional measurement using a CISPR peak detector has to prove that the peak emission is not more than 20 dB higher than the average emission.

As an exception of the quasi peak detector rule, the field strength limits for periodic operation, described in section 2.2 of this document, are based on the use of an averaging detector. As mentioned in section 2.2.3, this can be an advantage if the transmitter is activated in short bursts only. For example, if the transmitter is switched on only for 10 ms within the 100 ms averaging interval, the radiated field strength can be 10 times larger than the limits would be if the transmitter were on for the full 100 ms averaging window.

The fundamental and spurious emission limits outlined in sections 2.1 through 2.4 of this application note have to be measured in the following frequency ranges:

- For transmitters, from the lowest radio frequency generated in the device up to the tenth harmonic of the highest fundamental frequency.
- For receivers, from the lowest radio frequency generated in the device up to:
  - 2 GHz if the highest frequency generated in the device or to which the device tunes is between 108 and 500 MHz,
  - 5 GHz if the highest frequency generated in the device or to which the device tunes is between 500 MHz and 1 GHz, or
  - The fifth harmonic of the highest frequency generated in the device or to which the device tunes, if that frequency is higher than 1 GHz.

2.6 Summary of US Regulations

In the US, the regulations governing unlicensed wireless products fall into two broad categories: periodic devices and ISM-band devices. The type of application and the communications range determine the appropriate band and FCC classification to use. As an aid to this selection, the flow chart in Figure 2 depicts a decision path for choosing frequencies and transmit power limits.

Note: The section and table numbers in the flow chart are in reference to this document.

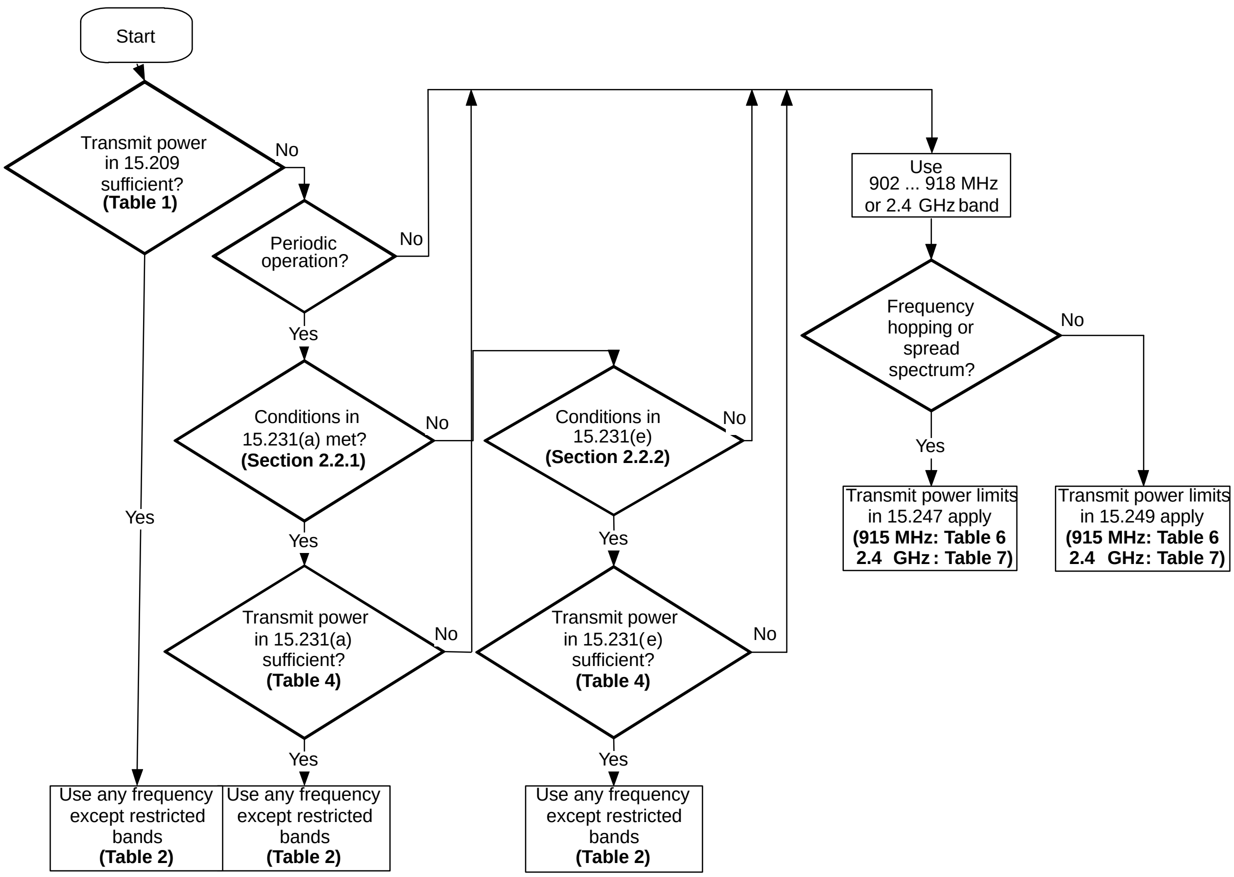

Figure 2. FCC Frequency and Transmit Power Decision Procedure For Non-Specific Unlicensed Operation

3 Regulations in the European Union

In the European Union, the regulations governing low power wireless devices are essentially defined by two separate bodies. One group defines the allocation of frequency bands and their use, and another group defines the test methodologies and general transceiver specifications. In this application note, the frequency band information is discussed in section 3.1, and the test methodologies and transceiver specifications are described in section 3.2.

3.1 Frequency Allocation and Use

In the EU, low power wireless devices are generally referred to as short-range devices, or SRD. The allocation of frequency bands and their use in the EU are based on recommendations by the Electronic Communications Committee (ECC), which is part of the European Conference of Postal and Telecommunication Administration (CEPT). The ECC document covering SRD is ERC/REC 70-03. The 45 member countries of the CEPT must then adopt these recommendations into law for them to be binding, so there are occasionally differences between the member countries.

Generally, the ECC recommendation defines 13 different types of SRD applications. The application type and the corresponding ERC/REC 70-03 annex number are listed in Table 8.

Table 8. List of Applications Defined in ERC-REC 70-03

Annex #	Application
1	Non-specific Short Range Devices
2	Equipment for Detecting Avalanche Victims
3	Local Area Networks, RLANs and HIPERLANs
4	Automatic Vehicle Identification for Railways
5	Road transport and traffic Telematics
6	Equipment for detecting Movement and Equipments for Alert
7	Alarms
8	Model Control
9	Inductive Applications
10	Radio Microphones
11	RF Identification Systems
12	Ultra Low Power Medical Implants
13	Wireless Audio Applications

The idea behind this application list is to protect some frequency bands for dedicated purposes. Alternatively, any application can be defined as a *non-specific short range device*. For example, an alarm system can be built using either a dedicated frequency band for alarms or a band allocated for non-specific short-range devices. Using the dedicated band has the advantage that no other applications are allowed to use that band, which decreases the probability of interference. Using a general purpose band might have the advantage of more readily available components, but it would have to take into account that other applications may use this frequency band, resulting in a higher probability of interference.

The ECC recommendation 70-03 defines both the maximum transmit power and limits to the duty cycle and the bandwidth of the transmitter for each allocated frequency band. Table 9 lists the frequencies and the limits for non-specific short range devices for the frequency range between 433 MHz and 2.4835 GHz.

Table 9. Frequency Bands For Non-Specific Short Range Devices in Europe

Frequency Band	ERP	Duty Cycle	Channel Bandwidth	Remarks
433.05 – 434.79 MHz	+10 dBm	<10%	No limits	No audio and voice
433.05 – 434.79 MHz	0 dBm	No limits	No limits	≤– 13 dBm/10 kHz, no audio and voice
433.05 – 434.79 MHz	+10 dBm	No limits	<25 kHz	No audio and voice
868 – 868.6 MHz	+14 dBm	< 1%	No limits	
868.7 – 869.2 MHz	+14 dBm	< 0.1%	No limits	
869.3 – 869.4 MHz	+10 dBm	No limits	< 25 kHz	Appropriate access protocol required
869.4 – 869.65 MHz	+27 dBm	< 10%	< 25 kHz	Channels may be combined to one high speed channel
869.7 -870 MHz	+7 dBm	No limits	No limits	
2400 – 2483.5 MHz	+7.85 dBm	No limits	No limits	Transmit power limit is 10-dBm EIRP

A selected list of additional frequency band allocations between 300 MHz and 2500 MHz for specific applications is provided in Table 10.

Table 10. Frequency Band For License-Free Specific Applications in Europe

Frequency Band	Application	ERP	Duty Cycle	Channel Bandwidth
402 – 405 MHz	Ultra Low Power medical Implants	–16 dBm	No limits	25 kHz(1)
868.6 – 868.7 MHz	Alarms	+10 dBm	< 0.1%	25 kHz(1)
869.2 – 869.25 MHz	Social Alarms	+10 dBm	< 0.1%	25 kHz
869.25 – 869.3 MHz	Alarms	+10 dBm	< 0.1%	25 kHz
869.65 -869.7 MHz	Alarms	+14 dBm	< 10%	25 kHz
863 – 865 MHz	Radio Microphones	+10 dBm	No limits	200 kHz
863 -865 MHz	Wireless Audio Applications	+10 dBm	No limits	300 kHz
1785 – 1800 MHz	Radio Microphones	+7.85 dBm	No limits	200 kHz
2400 – 2483.5 MHz	Wideband data transmission	+17.85 dBm	No limits	No limits(2)
2446 – 2454 MHz	Railway applications	+24.85 dBm	No limits	No limits
2400 – 2483.5 MHz	Motion sensors	+11.85 dBm	No limits	No limits
2446 – 2454 MHz	RFID	+24.85 dBm	No limits	No limits
2446 – 2454 MHz	RFID	+33.85 dBm	< 15%	No limits

(1) The whole frequency band may be used as one channel for high speed data transmission
(2) Maximum power density ≤ 7.85 dBm/1 MHz for DSSS systems and ≤ 17.85 dBm/100 kHz for FHSS systems

Table 9 and Table 10 both give the maximum transmit power in terms of the effective radiated power (ERP). As mentioned in section 1.1 in this application note, the ERP is related to the EIRP by the relation ERP = EIRP – 2.15 dB. The odd ERP numbers in Table 9 and Table 10 for frequency bands above 1 GHz come from the fact that ERC/REC 70-03 defines the power limits for these frequency bands in terms of the EIRP instead of the ERP.

For both Table 9 and Table 10, the duty cycle is defined as the maximum total transmitter on time as a fraction, expressed as a percentage, of the total time in a one hour period. Additionally, the duration of one individual transmission and the minimum off time between two consecutive transmissions are limited, as detailed in Table 11.

Table 11. Duty Cycle Limits According to ERC-REC 70-03

Duty Cycle Limit	Total *On* Time Within One Hour	Maximum *On* Time of One Transmission	Minimum *Off* Time of Two Transmission
< 0.1%	3.6 seconds	0.72 seconds	0.72 seconds
< 1%	36 seconds	3.6 seconds	1.8 seconds
< 10%	360 seconds	36 seconds	3.6 seconds

3.2 *Compliance Testing and Certification Process*

The procedure required to bring wireless equipment to the EU market is outlined in the *Directive 199/5/EC of the European Parliament and of the Council* (R&TTE directive). The R&TTE directive is based on self-declaration, that is, the manufacturer who supplies wireless equipment to the market declares that the product satisfies the legal requirements. The routes to the compliance declaration are outlined in the annexes II to V of the directive.

Annex II: The manufacturer declares conformity and establishes technical documentation (for receivers only).

Annex III: The manufacturer carries out essential radio tests defined in the harmonized standards.

Annex IV: Annex III plus assessment by a notified body if harmonized standards are not fully applicable.

Annex V: The manufacturer establishes a full quality assurance system, where a notified body can assess the quality assurance system, not the individual products.

In any case, the entity that places the equipment on the market is responsible for its compliance.

Harmonized standards for low power wireless devices are defined by the European Telecommunications Standards Institute, or ETSI. These standards are available at the ETSI web site: www.etsi.org. As with the ECC recommendations, these standards have to be translated into national law by all EU countries for them to be enforceable. Non-EU members may use these standards for regulatory purposes. The most important harmonized standard for low power wireless devices in the frequency range between 25 MHz and 1 GHz is EN 300 220. For frequencies between 1 GHz and 40 GHz, the harmonized standard is EN 300 440 applies. Additional standards for electromagnetic compatibility (EMC) and safety, such as EN 300 683 and EN 301 489, are also applicable. The use of harmonized standards according to annex III mentioned above is the most widely used path to the compliance declaration.

Sometimes harmonized standards are not applicable. In these cases, according to Annex IV, a notified body, that is a specially certified test laboratory, has to asses the product.

The harmonized standards from EN 300 320 for transmitters and receivers are summarized in below in sections 3.2.1 and 3.2.2, respectively.

3.2.1 Transmitter Tests

The transmitter tests in EN 300 220 distinguish between narrow band and wide band systems. A radiator is considered to be a wide band transmitter if it works in a continuous frequency band covering more than 25 kHz that is not subdivided into discrete channels. Otherwise, it is called a narrow band transmitter.

The required transmitter tests, as defined in EN 300 220, and the corresponding clauses, are:

- **Frequency error (clause 8.1)**

  For narrow band systems, the frequency error is the difference between the measured frequency and the nominal frequency under all operating conditions. For wide band systems, the frequency difference between normal and extreme temperature and supply voltage conditions is used.

  The allowed frequency error depends on whether the transmitter is fixed, mobile, or portable. A transmitter is fixed if it is in a permanent location, mobile if it is fixed in a vehicle, and portable if it is intended to be carried, attached, or implanted

- **Conducted carrier power for equipment with antenna connectors (clause 8.2)**

  This clause refers only to equipment with a permanent external antenna connector. A CISPR quasi peak detector is used.

- **Effective radiated power (clause 8.3)**

  The effective radiated power is measured in an anechoic chamber or an open area test site specified in annex A of the standard.

- **Response to modulation frequencies (clause 8.4)**

  This clause applies to analog modulated narrow band systems only and gives limits to the modulation depth or frequency deviation.

- **Adjacent channel power (clause 8.5)**

  This clause applies to narrow band systems only. The power emitted into the adjacent channel is measured by a test receiver specified in annex B. For a somewhat pessimistic evaluation a normal spectrum analyzer can be used. The resolution bandwidth should be 9 kHz for a channel spacing of 12.5 kHz and 16 kHz for a channel spacing of 25 kHz.

- **Range of modulation bandwidth (clause 8.6)**

  The range of modulation bandwidth is measured on wide band systems instead of the adjacent channel power. It is defined as the difference between the two frequencies at which the power envelope reaches the spurious emission limit of –36 dBm. The range of modulation bandwidth is measured with spectrum analyzer in maximum hold mode.

- **Spurious emissions (clause 8.7)**

  Spurious emissions are measured in an anechoic chamber or an open area test site specified in annex A to the standard. A CISPR quasi peak detector is used.

- **Frequency stability under low voltage conditions (clause 8.8)**

  This test has to be performed for battery driven equipment. Its purpose is to ensure that the either the transmitter disables itself, or remains on channel (for narrow band equipment) or in the assigned frequency band (for wide band equipment) if the battery runs empty.

- **Duty cycle (clause 8.9)**

The test limits for wide band transmitters are summarized in Table 12 and the test limits for digitally modulated narrow band transmitters are shown in Table 13.

Table 12. Test Limits For Wide-Band Transmitters

Test Case (Clause)	Limit
8.1 Frequency error (drift)	±100 ppm
8.2 and 8.3 Carrier power or ERP	According to ERC-REC 70-03
8.6 Range of modulation bandwidth	Band edges according to Table 5 or Table 6
8.7 Spurious emissions, operating	< 1 GHz: –36 dBm < 1 GHz at broadcast frequencies: – 54 dBm > 1 GHz: – 30 dBm
8.7 Spurious emissions, stand by	< 1 GHz: –57 dBm > 1 GHz: –47 dBm
8.8 Frequency stability under low voltage conditions	Remain in the band as long as the transmit power is larger than the spurious limits according to clause 8.7

Table 13. Test Limits For Digitally Modulated Narrow Band Transmitters

Test Case (Clause)	Limit for 10-kHz/12.5-kHz Channel BW	Limit for 20-kHz/25-kHz Channel BW
8.1 Frequency error, f < 500 MHz	Fixed station: ±1 kHz Mobile station: ±1.5 kHz Portable station: ±2.5 kHz	Fixed station: ±2 kHz Mobile station: ±2 kHz Portable station: ±2.5 kHz
8.1 Frequency error, f > 500 MHz	Nothing specified	Fixed station: ±2.5 kHz Mobile station: ±2.5 kHz Portable station: ±3 kHz
8.2 and 8.3 Carrier power or ERP	According to ERC-REC 70-03 (see Table 5 and Table 6)	According to ERC-REC 70-03 (see Table 5 and Table 6)
8.5 Adjacent channel power	Normal test conditions: –20 dBm Extreme test conditions: –15 dBm	Normal test conditions: –37 dBm Extreme test conditions: –32 dBm
8.7 Spurious emissions, operating	< 1 GHz: –36 dBm < 1 GHz at broadcast frequencies: –54 dBm > 1GHz: –30 dBm	
8.7 Spurious emissions, stand by	< 1 GHz: –57 dBm > 1 GHz: –47 dBm	
8.8 Frequency stability under low voltage conditions	Remain on channel as long as the transmit power is larger than the spurious limits according to clause 8.7	

3.2.2 Receiver Tests

Receiver tests are also defined in EN 300 220. These tests include selectivity, sensitivity, and spurious emissions. The standard also defines three classes of receivers based on the required reliability.

Receivers are classified as standard reliable (class 3), medium reliable (class 2), or highly reliable (class 1). If a malfunction of the radio link does not cause more than an inconvenience which can simply be overcome by other means such as manual operation, a class 3 receiver is sufficient. If a malfunction of the radio link causes an inconvenience which cannot simply be overcome, the receiver has to meet the specifications for class 2. Class 1 receivers are required if a malfunction may result in a physical risk to persons.

The receiver test defined in EN 300 220, and the corresponding clauses, are:

- **Adjacent channel selectivity – in band (clause 9.1)**

  The receiver adjacent channel selectivity is a measure of the receiver's capability to receive a wanted signal in the presence of an unmodulated interferer at an offset from the wanted frequency equal to the channel spacing (for instance 25 kHz). A modulated signal with a level 3 dB above the sensitivity limit is applied to the receiver. An unmodulated interferer is also applied to the receiver and its level is increased until the receiver misses the specified performance criterion, for instance, the bit error rate.

This usually happens at an interferer level larger than the level of the wanted signal. The adjacent level selectivity is the ratio of the interferer level to the level of the wanted signal.

- **Adjacent band selectivity (clause 9.2)**

  The receiver adjacent band selectivity is a measure of the receiver's capability to receive a wanted signal in the presence of an unmodulated interferer at the edge of the assigned frequency band according to Table 9 or Table 10. A modulated signal with a level 3 dB above the sensitivity limit is applied to the receiver. An unmodulated interferer on the band edge is applied to the receiver and its level is increased until the receiver misses the specified performance criterion, for instance, the bit error rate. This usually happens at an interferer level larger than the level of the wanted signal. The adjacent band selectivity is the ratio of the interferer level to the level of the wanted signal

- **Blocking or desensitization (clause 9.3)**

  The receiver blocking performance is a measure of the receiver's capability to receive a wanted signal in the presence of an unmodulated interferer at any frequencies except spurious responses and frequencies tested under clauses 9.1 and 9.2. Again, a modulated signal with a level 3 dB above the sensitivity limit is applied to the receiver. The interferer is tuned to offset frequencies of 1 MHz, 2 MHz, 5 MHz, and 10 MHz from the carrier frequency. For each interferer frequency, the maximum interferer level for which the receiver meets its specified performance criterion is recorded. The blocking is the worst case ratio of the interferer levels to the level of the wanted signal.

- **Spurious radiation (clause 9.4)**

  Spurious radiations from a receiver are measured in the same way as spurious radiations of transmitters.

The test limits for receivers are summarized in Table 14.

Table 14. Test Limits For Receivers

Test Case (Clause)	Limit for Class 1 Receiver	Limit for Class 2 Receiver	Limit for Class 3 Receiver
9.1 Adjacent channel	Channel spacing ≤ 25 kHz: 60 dB Channel spacing > 25 kHz: 70 dB	Not specified	Not specified
9.2 Adjacent band	60 dB	Not specified	Not specified
9.3 Blocking	84 dB for all frequencies	±1 MHz: 30 dB ±2 MHz: 35 dB ±5 MHz: 50 dB ±10 MHz: 60 dB	Not specified
9.4 Spurious radiation	< 1 GHz: –57 dBm > 1 GHz: –47 dBm		

4 Design Guidelines For Meeting Regulatory Requirements

All Texas Instruments low power wireless devices have been proven to meet the regulatory requirements in the US and EU. In order to produce a compliant end-product, the designer should observe the following guidelines:

- DC supply lines to the IC should have decoupling capacitors close to the IC.
- The printed circuit board (PCB) should have a solid ground plane in the RF section. Avoid cutouts or slots in this ground layer. Such slots can act as antennas and generate unwanted emissions.
- Study the harmonics specification of the IC and use a low-pass or band-pass filter in the transmit path to suppress the harmonics sufficiently. If possible, chose the transmit frequency such that the harmonics do not fall into restricted bands.
- In most cases shielding may be necessary to reduce spurious emissions. If that is the case, filter all lines leaving the shielded case with decoupling capacitors close to the shield inside the shielding case.
- Chose proper values of decoupling capacitors. A large capacitance value is not always the best. Good results are achieved with capacitors which are in series resonance with their parasitic inductance at the RF frequency that needs to be filtered out.

- The loop bandwidth of the PLL oscillator can have an impact on the range of modulation bandwidth or adjacent channel power of a transmitter and the adjacent channel rejection of a receiver. Design the PLL loop filter carefully according to the data rate requirements.
- In case of battery driven equipment, use a brownout detector to switch off the transmitter before the PLL looses lock due to a low battery voltage.

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