Application Note AN-00126

Introduction

This application note is designed to give the reader a basic understanding of the legal and technical considerations for operation of RF devices in the 902–928MHz band. The use of these frequency bands varies considerably worldwide, so it should be recognized that this application note is intended for designers utilizing Linx RF modules and planning for operation within the United States.

When working with RF, a clear distinction should always be made between what is technically possible and what is legally acceptable. Achieving a solution that meets technical objectives but cannot be legally sold or operated serves little use. As such, issues of legality should be given high priority.

Legal Considerations

In the United States, the Federal Communications Commission (FCC) is responsible for the regulation of all RF devices. These regulations are contained in the Code of Federal Regulations (CFR), Title 47. Title 47 is made up of numerous volumes; however, all regulations applicable to operation in the 902–928MHz band are contained in volume 0-19. Partial excerpts are included at the end of this document; however, it is strongly recommended that a full copy of the code be obtained from your local government bookstore, the Government Printing office <http://bookstore.gpo.gov/> or the FCC website <http://wireless.fcc.gov/rules.html>.

What Is Unlicensed Operation?

Certain bands within the RF spectrum are available for unlicensed operation. The term unlicensed is often misunderstood. The manufacturer of a product designed for unlicensed operation is not exempt from testing and/or certification. Indeed, both the transmitter and receiver must be tested by a qualified testing laboratory. However, once the necessary approvals are received, the end user can then operate the product without further obligation or licensing.

The frequencies from 902–928MHz are allocated for a wide variety of unlicensed applications. These include unlicensed Part 15 devices as well as Part 18 Industrial/Scientific/Medical (ISM) devices.

What Must I Do to Be Unlicensed?

Part 15 requirements for many bands are somewhat obscure and difficult to interpret. Thankfully, the regulations of Part 15 for the 902–928MHz band are very straightforward. There are no restrictions on the content or duration of transmissions, only factors such as power output, bandwidth, harmonic and spurious emissions.

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While Linx modules are inherently designed to meet these requirements, it is important to note that external factors such as layout, antenna type and output power can affect both module performance and compliance. While these issues may appear formidable, they are generally not.
By choosing a correct operational frequency and using a pre-made RF module, a product designer's burden is greatly reduced. Since the approval procedures for transmitters and receivers are quite different, let's look at each separately.

Receiver Procedure

The receiver is considered an unintentional radiator and is subject to authorization under the Declaration of Conformity process. This is a simple process in which an accredited laboratory tests the product to ensure that the equipment complies with FCC standards. An FCC filing or submittal is not required unless specifically requested pursuant to Section 2.1076. The test results should be maintained within the applicant's files.

Following successful completion of this process, the end product should be labelled as prescribed by the FCC. Further information on labeling may be obtained at (http://fjallfoss.fcc.gov/oetcf/kdb/forms/FTSSearchResultPage.cfm?id=27980&switch=P).

Transmitter Procedure

The transmitter is an intentional radiator and subject to certification. In most instances, users of modules manufactured by Linx will seek certification under part 15.247 for Spread Spectrum modules or under 15.249 for narrowband modules. An exception to this is RF modules which have been precertified by Linx under the modular approval process.

In instances where certification is required, testing will need to be performed by an accredited laboratory. In most cases it is not necessary to be present for testing and the laboratory will prepare the filing paperwork. Certifications were once issued by the FCC directly, but now independent laboratories are allowed to issue certification though the Telecommunication Certification Body (TCB) program which has greatly streamlined the process.

Following successful testing, a report will be produced showing information about the testing and the device. A label displaying the applicant's FCC ID number along with FCC prescribed information will need to be placed on the certified product. Further information on labeling can be obtained at the website listed in the preceding section.

Now that a basic overview of legal issues has been covered, it is time to consider the technical issues of operation in these frequencies.

Benefits of Operation within the 902–928MHz Band

The first benefit of the 902–928MHz band is freedom from the tight limitations and application restrictions the FCC places on some other bands. In this band, virtually any analog or digital signal can be sent without restrictions on content or duration.

Second, higher legal output power allows the potential for much longer transmission distances.

Third, the propagation of frequencies in the 900MHz range is better than at higher frequencies such as 2.4GHz. Therefore, lower output power is needed to attain any particular distance, reducing transmitter power consumption.

Fourth is antenna size and compactness. A useful byproduct of higher frequency is shorter wavelength. This allows a ¼-wave antenna in the 900MHz range to typically be less than 3.25 inches in length. In fact, Linx's Antenna Factor division offers tiny surface mount antennas that are less than 0.65 inches in length, allowing for easy concealment in compact portable products.

Drawbacks to the 902–928MHz Band

The first drawback is the band's popularity (good in rock and roll, bad in RF). Products such as cordless phones have migrated to higher frequencies, but the growth of wireless and the benefits of the band make it likely to remain crowded.

Second is the potential for higher level interferers. In addition to its allocation for narrow-band devices, the 902–928MHz frequency range is also allocated for higher power devices. While Linx employs a variety of techniques to minimize the possible impact of such interference, it should be considered.

Third is the difficulty of export. Most countries outside the US do not allow similar operation in the 900MHz band, so it is usually impractical to export a device that operates in this range. Fortunately, nearby frequencies are standardized in large market areas such as Europe. Linx offers a selection of footprint compatible products, which accommodate domestic and export requirements with just a change of modules and antennas.

Summary

The 902–928MHz band is highly favorable due to minimal legal restrictions and excellent propagation characteristics. It is an ideal choice for analog and/or digital links, especially those that require reliability over long distances or which might be prohibited in other bands.

Appendix A—FCC CFR 47 Section 15.247

Operation within the bands 902–928MHz, 2400–2483.5MHz, and 5725–5850MHz.
(a) Operation under the provisions of this Section is limited to frequency hopping and digitally modulated intentional radiators that comply with the following provisions:

(1) Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25kHz or the 20dB bandwidth of the hopping channel, whichever is greater. Alternatively, frequency hopping systems operating in the 2400–2483.5MHz band may have hopping channel carrier frequencies that are separated by 25kHz or two-thirds of the 20dB bandwidth of the hopping channel, whichever is greater, provided the systems operate with an output power no greater than 125mW. The system shall hop to channel frequencies that are selected at the system hopping rate from a pseudo randomly ordered list of hopping frequencies. Each frequency must be used equally on the average by each transmitter. The system receivers shall have input bandwidths that match the hopping channel bandwidths of their corresponding transmitters and shall shift frequencies in synchronization with the transmitted signals.

(i) For frequency hopping systems operating in the 902–928 MHz band: if the 20dB bandwidth of the hopping channel is less than 250kHz, the system shall use at least 50 hopping frequencies and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 20 second period; if the 20dB bandwidth of the hopping channel is 250kHz or greater, the system shall use at least 25 hopping frequencies and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 10 second period. The maximum allowed 20dB bandwidth of the hopping channel is 500kHz.

(ii) Frequency hopping systems operating in the 5725–5850MHz band shall use at least 75 hopping frequencies. The maximum 20dB bandwidth of the hopping channel is 1MHz. The average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 30 second period.

(iii) Frequency hopping systems in the 2400–2483.5MHz band shall use at least 15 channels. The average time of occupancy on any channel shall not be greater than 0.4 seconds within a period of 0.4 seconds multiplied by the number of hopping channels employed. Frequency hopping systems may avoid or suppress transmissions on a particular hopping frequency provided that a minimum of 15 channels are used.

(2) Systems using digital modulation techniques may operate in the 902–928MHz, 2400–2483.5MHz, and 5725–5850MHz bands. The minimum 6dB bandwidth shall be at least 500kHz.

(b) The maximum peak conducted output power of the intentional radiator shall not exceed the following:

(1) For frequency hopping systems operating in the 2400–2483.5MHz band employing at least 75 non-overlapping hopping channels, and all frequency hopping systems in the 5725–5850MHz band: 1 watt. For all other frequency hopping systems in the 2400–2483.5MHz band: 0.125 watts.

(2) For frequency hopping systems operating in the 902–928MHz band: 1 watt for systems employing at least 50 hopping channels; and, 0.25 watts for systems employing less than 50 hopping channels, but at least 25 hopping channels, as permitted under paragraph (a)(1)(i) of this section.

(3) For systems using digital modulation in the 902–928MHz, 2400–2483.5MHz, and 5725–5850MHz bands: 1 Watt. As an alternative to a peak power measurement, compliance with the one Watt limit can be based on a measurement of the maximum conducted output power. Maximum Conducted Output Power is defined as the total transmit power delivered to all antennas and antenna elements averaged across all symbols in the signaling alphabet when the transmitter is operating at its maximum power control level. Power must be summed across all antennas and antenna elements. The average must not include any time intervals during which the transmitter is off or is transmitting at a reduced power level. If multiple modes of operation are possible (e.g., alternative modulation methods), the maximum conducted output power is the highest total transmit power occurring in any mode.

(4) The conducted output power limit specified in paragraph (b) of this section is based on the use of antennas with directional gains that do not exceed 6dBi. Except as shown in paragraph (c) of this section, if transmitting antennas of directional gain greater than 6 dBi are used, the conducted output power from the intentional radiator shall be reduced below the stated values in paragraphs (b)(1), (b)(2), and (b)(3) of this section, as appropriate, by the amount in dB that the directional gain of the antenna exceeds 6dBi.

(i) Systems operating in the 2400–2483.5MHz band that are used exclusively for fixed, point-to-point operations may employ transmitting antennas with directional gain greater than 6dBi provided the maximum peak output power of the intentional radiator is reduced by 1dB for every 3dB that the directional gain of the antenna exceeds 6dBi.

(ii) Systems operating in the 5725–5850MHz band that are used exclusively for fixed, point-to-point operations may employ transmitting antennas with directional gain greater than 6dBi without any corresponding reduction in transmitter peak output power.

(iii) Fixed, point-to-point operation, as used in paragraphs (b)(3)(i) and (b)(3)(ii) of this section, excludes the use of point-to-multipoint systems, omnidirectional applications, and multiple co-located intentional radiators transmitting the same information. The operator of the spread spectrum intentional radiator or, if the equipment is professionally installed, the installer is responsible for ensuring that the system is used exclusively for fixed, point-to-point operations. The instruction manual furnished with the intentional radiator shall contain language in the installation instructions informing the operator and the installer of this responsibility.

(c) Operation with directional antenna gains greater than 6dBi.

(1) Fixed point-to-point operation:

(i) Systems operating in the 2400–2483.5MHz band that are used exclusively for fixed, point-to-point operations may employ transmitting antennas with directional gain greater than 6dBi provided the maximum conducted output power of the intentional radiator is reduced by 1dB for every 3dB that the directional gain of the antenna exceeds 6dBi.

(ii) Systems operating in the 5725–5850MHz band that are used exclusively for fixed, point-to-point operations may employ transmitting antennas with directional gain greater than 6dBi without any corresponding reduction in transmitter conducted output power.

(iii) Fixed, point-to-point operation, as used in paragraphs (c)(1)(i) and (c)(1)(ii) of this section, excludes the use of point-to-multipoint systems, omnidirectional applications, and multiple co-located intentional radiators transmitting the same information. The operator of the spread spectrum or digitally modulated intentional radiator or, if the equipment is professionally installed, the installer is responsible for ensuring that the system is used exclusively for fixed, point-to-point operations. The instruction manual furnished with the intentional radiator shall contain language in the installation instructions informing the operator and the installer of this responsibility.

(2) In addition to the provisions in paragraphs (b)(1), (b)(3), (b)(4) and (c)(1)(i) of this section, transmitters operating in the 2400–2483.5MHz band that emit multiple directional beams, simultaneously or sequentially, for the purpose of directing signals to individual receivers or to groups of receivers provided the emissions comply with the following:

(i) Different information must be transmitted to each receiver.

(ii) If the transmitter employs an antenna system that emits multiple directional beams but does not do emit multiple directional beams simultaneously, the total output power conducted to the array or arrays that comprise the device, i.e., the sum of the power supplied to all antennas, antenna elements, staves, etc. and summed across all carriers or frequency channels, shall not exceed the limit specified in paragraph (b)(1) or (b)(3) of this section, as applicable. However, the total conducted output power shall be reduced by 1dB below the specified limits for each

3dB that the directional gain of the antenna/antenna array exceeds dBi. The directional antenna gain shall be computed as follows:

(A) The directional gain shall be calculated as the sum of 10 log (number of array elements or staves) plus the directional gain of the element or stave having the highest gain.

(B) A lower value for the directional gain than that calculated in paragraph (c)(2)(ii)(A) of this section will be accepted if sufficient evidence is presented, e.g., due to shading of the array or coherence loss in the beamforming.

(iii) If a transmitter employs an antenna that operates simultaneously on multiple directional beams using the same or different frequency channels, the power supplied to each emission beam is subject to the power limit specified in paragraph (c)(2)(ii) of this section. If transmitted beams overlap, the power shall be reduced to ensure that their aggregate power does not exceed the limit specified in paragraph (c)(2)(ii) of this section. In addition, the aggregate power transmitted simultaneously on all beams shall not exceed the limit specified in paragraph (c)(2)(ii) of this section by more than 8dB.

(iv) Transmitters that emit a single directional beam shall operate under the provisions of paragraph (c)(1) of this section.

(d) In any 100kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20dB below that in the 100kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30dB instead of 20dB. Attenuation below the general limits specified in Section 15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in Section 15.205(a), must also comply with the radiated emission limits specified in Section 15.209(a) (see Section 15.205(c)).

(e) For digitally modulated systems, the power spectral density conducted from the intentional radiator to the antenna shall not be greater than 8dBm in any 3kHz band during any time interval of continuous transmission. This power spectral density shall be determined in accordance with the provisions of paragraph (b) of this section. The same method of determining the conducted output power shall be used to determine the power spectral density.

(f) For the purposes of this section, hybrid systems are those that employ a combination of both frequency hopping and digital modulation techniques. The frequency hopping operation of the hybrid system, with the direct sequence or digital modulation operation turned off, shall have an average time of occupancy on any frequency not to exceed 0.4 seconds within a time period in seconds equal to the number of hopping frequencies employed multiplied by 0.4. The digital modulation operation of the hybrid system, with the frequency hopping operation turned off, shall comply with the power density requirements of paragraph (d) of this section.

(g) Frequency hopping spread spectrum systems are not required to employ all available hopping channels during each transmission. However, the system, consisting of both the transmitter and the receiver, must be designed to comply with all of the regulations in this section should the transmitter be presented with a continuous data (or information) stream. In addition, a system employing short transmission bursts must comply with the definition of a frequency hopping system and must distribute its transmissions over the minimum number of hopping channels specified in this section.

NOTE: Spread spectrum systems are sharing these bands on a noninterference basis with systems supporting critical Government requirements that have been allocated the usage of these bands, secondary only to ISM equipment operated under the provisions of part 18 of this chapter. Many of these Government systems are airborne radiolocation systems that emit a high EIRP which can cause interference to other users. Also, investigations of the effect of spread spectrum interference to U. S. Government operations in the 902–928MHz band may require a future decrease in the power limits allowed for spread spectrum operation.

(i) Systems operating under the provisions of this section shall be operated in a manner that ensures that the public is not exposed to radio frequency energy levels in excess of the Commission's guidelines. See Section 1.1307(b)(1) of this chapter.

Appendix B—FCC CFR 47 Section 15.249

Section 15.249 Operation within the bands 902–928MHz, 2400–2483.5MHz, 5725–5875MHz, and 24.0–24.25GHz.
(a) Except as provided in paragraph (b) of this section, the field strength of emissions from intentional radiators operated within these frequency bands shall comply with the following:

(b) Fixed, point-to-point operation as referred to in this paragraph shall be limited to systems employing a fixed transmitter transmitting to a fixed remote location. Point-to-multipoint systems, omnidirectional applications, and multiple colocated intentional radiators transmitting the same information are not allowed. Fixed, point-topoint operation is permitted in the 24.05–24.25GHz band subject to the following conditions:

(1) The field strength of emissions in this band shall not exceed 2500 millivolts/meter.

(2) The frequency tolerance of the carrier signal shall be maintained within ±0.001% of the operating frequency over a temperature variation of –20 degrees to +50 degrees C at normal supply voltage, and for a variation in the primary supply voltage from 85% to 115% of the rated supply voltage at a temperature of 20 degrees C. For battery operated equipment, the equipment tests shall be performed using a new battery.

(3) Antenna gain must be at least 33dBi. Alternatively, the main lobe beamwidth must not exceed 3.5 degrees. The beamwidth limit shall apply to both the azimuth and elevation planes. At antenna gains over 33dBi or beamwidths narrower than 3.5 degrees, power must be reduced to ensure that the field strength does not exceed 2500 millivolts/meter.

(c) Field strength limits are specified at a distance of 3 meters.

(d) Emissions radiated outside of the specified frequency bands, except for harmonics, shall be attenuated by at least 50dB below the level of the fundamental or to the general radiated emission limits in Section 15.209, whichever is the lesser attenuation.

(e) As shown in Section 15.35(b), for frequencies above 1000MHz, the field strength limits in paragraphs (a) and (b) of this section are based on average limits. However, the peak field strength of any emission shall not exceed the maximum permitted average limits specified above by more than 20dB under any condition of modulation. For point-to-point operation under paragraph (b) of this section, the peak field strength shall not exceed 2500 millivolts/meter at 3 meters along the antenna azimuth.

(f) Parties considering the manufacture, importation, marketing or operation of equipment under this section should also note the requirement in Section 15.37(d).

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