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Before the
Federal Communications Commission
Washington, D.C. 20554

Amendment of Parts 2 and 15 of the Commission's Rules Regarding Spread Spectrum Transmitters	)))	ET Docket No. 96-8 RM-8435, RM-8608, RM-8609

REPORT AND ORDER
(Proceeding Terminated)

Adopted: April 3, 1997 **Released:** April 10, 1997

By the Commission:

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I. INTRODUCTION

1. By this action, the Commission is amending Parts 2 and 15 of its rules regarding the operation of spread spectrum transmission systems in the 902-928 MHz, 2400-2483.5 MHz and 5725-5850 MHz bands.[1] Specifically, the Commission is eliminating the limit on directional gain antennas for spread spectrum transmitters operating in the 2450 MHz and the 5800 MHz bands. For spread spectrum transmitters operating in the 2450 MHz band, the Commission is implementing its proposal to require that the output power of the transmitter be reduced by 1 dB for every 3 dB that the directional antenna gain exceeds 6 dBi. The Commission is also reducing, from 50 to 25, the minimum number of channels required for frequency hopping spread spectrum systems operating in the 915 MHz band. It is also adopting a number of amendments to the spread spectrum regulations to clarify the existing regulations, to codify existing policies into the rules, and to update the current definitions. These changes to the rules will facilitate the growth of the spread spectrum industry by enabling and encouraging practical applications for these products. The new rules will expand the ability of equipment manufacturers to develop spread spectrum systems for unlicensed use. These systems will provide users with the flexibility to establish radio links without the delays and costs associated with formal frequency coordination and licensing. Such uses may include intelligent transportation system communications links; high speed Internet connections for schools, hospitals, and government offices; energy utility applications; PCS and cellular backbone connections; and T-1 common carrier links in rural areas. The new rules will also permit frequency hopping spread spectrum systems and wideband, multilateration Location Monitoring Service (LMS) systems to operate within the same frequency band with decreased potential for mutual interference problems.

[1] For simplicity, these bands will be referred to in this Report and Order as the 915 MHz, 2450 MHz and 5800 MHz bands.

II. BACKGROUND

2. Part 15 of the regulations permits the operation of radio frequency (RF) devices without a license from the Commission or the need for frequency coordination.[2] The technical standards for Part 15 transmission systems are designed to ensure that there is a low probability that these devices will cause harmful interference to other users of the spectrum.[3] Indeed, the primary operating conditions under Part 15 are that the operator must accept whatever interference is received and must correct whatever interference is caused.[4]

3. Spread spectrum communications systems use special modulation techniques that spread the energy of the signal being transmitted over a very wide bandwidth. The information to be conveyed is modulated onto a carrier frequency by some conventional technique, such as AM, FM or digital, and the bandwidth of the signal is deliberately widened by means of a spreading function.[5] This spreading reduces the power density of the signal at any frequency within the transmitted bandwidth, thereby reducing the probability of causing interference to other signals occupying the same spectrum. The spreading technique used in the transmitter is reversed in the receiver to enable detection and decoding of the signal. This reversal of the signal spreading process enables the suppression of strong undesired signals in the receiver. Spread spectrum systems are thus able to tolerate strong nonspread signals with a reduced likelihood of receiving harmful interference.[6]

4. Part 15 authorizes the unlicensed operation of spread spectrum transmitters within the 915 MHz, 2450 MHz and 5800 MHz frequency bands at higher power levels than would

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[2] *See* 47 CFR § 15.1 *et seq.*

[3] In order to reduce the potential for harmful interference to other radio services, the Commission generally requires that Part 15 transmitters operate at extremely low signal levels. In addition to requiring the use of low signal levels, the potential for generating harmful interference to other radio stations can be reduced through other methods, such as limiting the application for which a product can be used in a frequency band, thereby minimizing its proliferation.

[4] Should harmful interference occur, the operator of the Part 15 device is required to correct the interference problem immediately, even if correction of the problem requires ceasing operation of the system causing the interference. *See* 47 CFR § 15.5.

[5] Two types of spread spectrum systems are permitted under the Part 15 regulations: direct sequence systems and frequency hopping systems. Direct sequence systems modulate the carrier with a combined information signal and a much faster binary code signal. The binary code signal typically is a fixed-length, pseudorandom sequence of bits. It dominates the modulating function and is the direct cause of the spreading of the transmitted signal. Frequency hopping systems spread their energy by changing, or "hopping," the center frequency of the transmission in accordance with a pseudorandomly generated list of channels.

[6] The improvement in the signal-to-noise ratio is termed "processing gain." Additional discussion concerning processing gain is contained in para. 44-45 and in Appendix C.

normally be permitted for other unlicensed devices.[7] The current regulations limit spread spectrum systems to a maximum peak transmitter output power of one watt. When operating at that power level, the maximum directional gain of the associated antenna may not exceed 6 dBi, resulting in a maximum equivalent isotropically radiated power (EIRP) of four watts, *i.e.*, 6 dBW. Direct sequence systems must employ a minimum bandwidth of 500 kHz with a processing gain of at least 10 dB. Frequency hopping systems in the 915 MHz band must use at least 50 hopping channels with a maximum channel bandwidth of 500 kHz, while hopping systems in the 2450 MHz and 5800 MHz bands must use at least 75 hopping channels with a maximum channel bandwidth of 1 MHz.

5. In the *Notice of Proposed Rule Making* ("*Notice*") in this proceeding, the Commission proposed to amend Part 15 of its rules to permit the use of higher antenna gains, without a corresponding reduction in transmitter output power, for spread spectrum transmitters operating in the 5800 MHz band.[8] This proposal was in response to a Petition for Rule Making and Request for Immediate Waiver submitted by Western Multiplex Corporation (WMC).[9] In the *Notice*, the Commission also proposed to reduce the minimum number of channels required for frequency hopping systems operating in the 915 MHz band from 50 to 25 channels, along with a corresponding reduction in the maximum allowable transmitter output power.[10] This latter proposal was in response to a Petition for Rule Making submitted by SpectraLink Corporation (SpectraLink). On its own motion, the Commission also proposed several additional amendments to Part 15 of the rules regarding the maximum permitted spectral power density for direct sequence spread spectrum systems; the definitions of direct sequence, pseudorandom sequence, and frequency hopping systems; the acceptability of transmitters employing short duration transmissions; the measurement of processing gain; clarification of the limits on unwanted

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[7] *See* 47 CFR § 15.247. Unless otherwise noted, all references to the Part 15 spread spectrum regulations are to this rule section.

[8] *See Notice of Proposed Rule Making*, ET Docket No. 96-8, 11 FCC Rcd 3068 (1996), at para. 6-17. While the Commission stated that it was not inclined to provide a similar relaxation for the 2450 MHz band, it did request comments on eliminating the directional antenna gain for that band. *See Notice* at para. 11. Cylink Corp. (Cylink), Metricom, Inc. (Metricom), and Tetherless Access Ltd. also requested that the limit on maximum directional antenna gain also be deleted for systems in the 915 MHz band. The Commission rejected this latter request. *See Notice* at para. 9.

[9] *See* RM-8435. In addition, waivers were granted to WMC on October 3, 1994, and February 14, 1995, to Cylink on December 16, 1994, and to Atlantic Communications Sciences (ACS) on February 15, 1995, to operate spread spectrum transmission systems employing high directional antenna gains in the 2450 MHz and 5800 MHz bands. These waivers were due to expire on June 23, 1996, but were extended on June 18, 1996, for a two year period or until the effective date of the Report and Order in this proceeding, whichever is earlier. Spread spectrum systems operating under this waiver are required to meet all other standards contained in the current regulations. Further, the waivers are limited to equipment used for fixed point-to-point operations; point-to-multipoint and omnidirectional operations are prohibited. On November 5, 1996, similar waivers were granted to Microwave Data Systems (MDS) and Larus Corporation; on February 2, 1997, a similar waiver was granted to Wi-LAN Inc.

[10] *See Notice* at para. 26-34.

emissions; the coordination of frequency hopping transmitters; and the use of external radio frequency power amplifiers.[11] It further proposed that the changes to the regulations adopted in response to the *Notice* become effective upon the date of publication in the Federal Register in order to make the benefits resulting from the changes available as soon as possible.[12] Finally, the Commission denied a Petition for Rule Making from Symbol Technologies, Inc. (Symbol)[13] which requested that the minimum number of channels required for frequency hopping systems operating in the 2450 MHz or 5800 MHz bands be reduced from 75 to 20.[14]

6. Comments responding to the proposed changes to the rules were submitted by a number of parties. Generally, these comments were supportive of the Commission's proposals. The commenters also submitted numerous suggestions for improving or modifying the proposed rules. A list of the parties submitting comments is contained in Appendix A.

III. DISCUSSION

A. High gain directional antennas

1. Directional antenna gain limits.

7. In the *Notice*, the Commission proposed to eliminate the directional antenna gain limit for non-consumer, fixed, point-to-point spread spectrum systems operating in the 5800 MHz band.[15] The Commission indicated that there were few operators, especially mobile users, in the 5800 MHz band and, thus, the potential for harmful interference that could occur from the use of high gain directional antennas in this band was much lower, as compared to the 915 MHz and 2450 MHz bands.[16] While the Commission stated that it was not inclined to provide a similar relaxation for the 2450 MHz band, comments were requested on whether the directional antenna gain limit could also be eliminated for that band. The Commission declined to propose a similar

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[11] *See Notice* at para. 35-44.

[12] *See Notice* at para. 45.

[13] *See* RM-8608.

[14] *See Notice* at para. 18-25 and at para. 49.

[15] *See Notice* at para. 9-11.

[16] When the spread spectrum rules were originally adopted, there was no limit on the amount of directional antenna gain that could be employed with the transmitters. At that time, there were few other radio communication systems operating in these bands and little potential that interference would be caused to other users. The Commission did, however, express its concern in permitting high powered, unlicensed operation in these bands. Eventually, because of this concern that interference would be caused to the licensed radio services, the Commission amended its regulations to limit the maximum peak EIRP to 4 watts.

change to the antenna directional limit for spread spectrum systems operating in the 915 MHz band.

8. In general, the commenting parties support the proposal to eliminate the limit on directional antenna gain in the 5800 MHz band. Cellular companies and utilities, including AT&T Wireless Services (AT&T), Columbia Gas Transmission, Oneonta Telephone Company, Inc. (Oneonta Telephone), Rural Cellular Corporation (Rural Cellular) and others, also support the use of high gain directional antennas. Apple Computer, Inc. (Apple) states that longer-reach unlicensed communications are an important step for the expansion of the Internet and the National Information Infrastructure (NII).[17] Apple adds that unlicensed transmitters employing directional, narrow-beam antennas support the goals of the NII band by enabling rapid setup, lower costs, greater frequency reuse and a higher information capacity. The Telecommunications Industry Association, Fixed Point-to-Point Communications Section (TIA Fixed) was the only party strongly to oppose the Commission's proposal to eliminate the limit on directional antenna gain at 5800 MHz. Specifically, it opposes unlicensed, uncoordinated long-range operations in the 5800 MHz band, arguing that longer path lengths, providing cost-effective, high-speed, large capacity capabilities, are already available in the 18, 23 and 38 GHz band to support the NII on a licensed basis.[18]

9. Many of the commenting parties support permitting the use of high gain directional antennas in the 2450 MHz band.[19] Cylink Corp. (Cylink) and WMC state that, under waivers issued by the Commission, they have been operating systems in the 2450 MHz band with directional antenna gains greater than the 6 dBi limit with no reports of interference.[20] Cylink, Mulcay Consulting Associates (MCA) and WMC argue that limiting the EIRP of spread spectrum devices in the 2450 MHz band may adversely impact the ability of Part 15 devices to share the band with Part 18 ISM devices.[21] WMC states that limiting the EIRP to 6 dBW will cause the received signal level from Part 15 communications transmitters to fall below the background radiation from industrial, scientific and medical (ISM) devices operating under Part 18 of the rules, making these applications unusable.[22] Similarly, Metricom, Inc. (Metricom) states that the greatest potential for interference in the 2450 MHz and 5800 MHz bands is from Part 18 ISM

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[17] In particular, the 5800 MHz band frequencies were also adopted for the NII/SUPERNet band. *See Report and Order* in ET Docket 96-102, adopted January 9, 1997, FCC 97-5.

[18] *See* TIA Fixed Reply Comments at 2.

[19] *See*, for example, comments from Apple , AT&T, Columbia Gas Transmission, Cylink, Gabriel Electronics, Inc. (Gabriel Electronics), Metricom, Microwave Communications Technology Inc. (MCT), OCOM Corporation (OCOM), Part 15 Coalition, and US West, Inc. (US West).

[20] *See* Cylink Comments at 8; WMC Comments at 5.

[21] *See* Cylink Comments at 5-6; MCA Comments at 2; WMC Comments at 4.

[22] *See* WMC Comments at 2.

transmissions rather than from Part 15 transmitters.[23]

10. Several parties opposed eliminating the limit on directional antenna gain for the 2450 MHz band.[24] The commenters' primary objections are that the 2450 MHz band is more heavily used than the 5800 MHz band and contains both mobile and fixed users. Cushcraft Corporation (Cushcraft) is concerned that high-gain, fixed point-to-point operations may cause too much interference to systems employing lower gain antennas, such as wireless local area network systems (LANs).[25] Cushcraft adds that the increasing proliferation of mobile and portable users in the 2450 MHz is not compatible with high gain, fixed, point-to-point systems. Fusion Systems Corporation (Fusion) points out that compatibility problems may exist between the primary ISM users and the fixed or mobile communications users in the 2450 MHz band.[26] Fusion recommends adopting rules that caution manufacturers and users operating in any of the ISM bands that in-band interference may be intolerable unless susceptibility standards, similar to those currently employed in Europe, are applied to their systems. Fusion Lighting, Inc. (Fusion Lighting) raised identical concerns.[27]

11. Based on the comments received, the Commission is amending its regulations to eliminate the existing transmitter output power penalty for Part 15 spread spectrum systems operating with high gain directional antennas in the 2450 MHz and 5800 MHz bands.[28] The Commission recognizes the advantages of being able readily to establish radio links capable of transmission distances of 10 km, or greater, without the delays and costs associated with formal frequency coordination and licensing.[29] The ability to establish quickly such transmission links could be critical in emergency situations. Directional antennas can significantly reduce the potential for harmful interference to other radio operations in cases where the location of the

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[23] *See* Metricom Comments at 4.

[24] *See* comments from Adtran, Cushcraft Corporation (Cushcraft), Digital Wireless Corporation (Digital Wireless), Rockwell International Corporation (Rockwell), Telecommunications Industry Association, Wireless Consumer Communications Section (TIA Wireless), and TIA Fixed.

[25] *See* Cushcraft Comments at 3.

[26] *See* Fusion Comments at 1-5.

[27] *See* Fusion Lighting Comments at 1-3.

[28] The Commission is also adopting a more relaxed restriction on output power for the 2450 MHz band in order to decrease the potential for interference to other services. *See* discussion on reduction in output power for the 2450 MHz band contained in paragraphs 16-17 of this Report and Order.

[29] *See Notice* at para. 10.

directional systems is coordinated and there is a low preponderance of mobile systems.[30] When dealing with fixed radio applications, the use of directional antennas can be particularly important in allowing nearby fixed radio systems to co-exist within the same frequency band. Radio systems located outside the directional beam of the antenna pattern have a low probability of receiving interference. However, radio systems that are located in the main beam of the directional antenna will have a much higher potential for receiving interference, in particular because of the higher signal levels caused by the antenna gain. Thus, mobile systems are particularly susceptible to interference from fixed stations since they can move into the main beam of the fixed station.

12. There are a significant number of mobile operations in the 915 MHz band.[31] It was for this reason that the Commission decided not to eliminate the antenna gain limits for the 915 MHz band. Similarly, the number of mobile applications has continued to increase in the 2450 MHz band. The 2450 MHz band is allocated for ISM devices under Part 18 of the rules, U.S. Government stations, the Private Land Mobile Radio Services under Part 90, the Private Operational-Fixed Microwave Services under Part 94, Television Broadcast Auxiliary Stations under Part 74, and the Amateur Radio Service under Part 97. The primary increase in the number of number of licensed mobile units is from surveillance and other systems operating under the Public Safety Radio Services under Part 90. Further, as in the 915 MHz band, the number of Part 15 systems appearing in the 2450 MHz band is continuing to increase, especially for devices such as wireless local area network systems. Accordingly, the Commission was not inclined in the *Notice* to eliminate the limit on directional antenna gain for this band. However, as indicated by WMC, the 2450 MHz band has a significant background noise level, primarily from the operation of microwave ovens and other ISM devices.[32] Further, while the background noise level for the 5800 MHz band is not as high as the 2450 MHz band, this noise level is expected to increase as the cost of equipment in the 5800 MHz band continues to decline due to improvements in technology and the number of users in this band increase.[33] The use of directional antennas will help transmission systems to overcome these noise levels in both bands,

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[30] A directional antenna operates by taking radio frequency power from the transmitter and concentrating that power in a specific direction, similar to the action of a reflector in a search light. While the signal strength is much stronger in the desired direction, the signal level in other directions is considerably reduced. The reference to "mobile systems" also, for the purpose of this Report and Order, includes temporary fixed systems since the location of the temporary fixed system may not be known or coordinated prior to operation. For many temporary fixed systems, it is the receiving site that remains in a fixed location.

[31] The 915 MHz band is allocated for ISM devices under Part 18 of the rules, U.S. Government radiolocation, U.S. Government fixed and mobile operations, land mobile operations under Part 90, and amateur operations under Part 97. In addition, there are a significant number of Part 15 devices operating in the 915 MHz band, including wireless computer local area network systems and cordless telephones.

[32] *See* WMC Comments at 4.

[33] The 5800 MHz band is allocated for operation by ISM devices under Part 18 of the rules, U.S. Government stations, and the Amateur Radio Service under Part 97.

permitting their use by important communication services. Accordingly, the Commission believes that the limit on directional antenna gain could be relaxed for both the 2450 MHz and 5800 MHz bands without substantially increasing the potential for harmful interference to the licensed radio services.[34] However, as discussed in the next section, the Commission also believes that some corresponding reduction in the transmitter output power is necessary for transmitters operating in the 2450 MHz band.

13. The Commission does not agree with Fusion that additional regulations should be adopted cautioning manufacturers and users that in-band interference may be intolerable unless susceptibility standards are applied to their systems. A note at the end of the spread spectrum rule section already advises that potential interference may occur from other operations in these frequency bands. In addition, the transmitters must already be labelled with a statement that operation under Part 15 is not protected against harmful interference.[35] Further, the Commission has chosen not to establish susceptibility standards under its regulations for other Part 15 products, but has allowed industry to develop these standards as necessary.[36] Further, the Commission's authority to establish susceptibility standards is limited to home electronic equipment and systems.[37] The majority of the spread spectrum systems, especially those systems employing directional antennas, are not classified as home electronic equipment.

14. The manufacturers and operators of spread spectrum transmitters are reminded that the operation of Part 15 devices is subject to the conditions that any received interference, including interference from ISM operations, must be accepted and that harmful interference may not be caused to other radio services. Should the operation of these systems cause harmful interference, the operator of the Part 15 system is required to correct the interference problem, even if such correction requires the cessation of operation of the Part 15 transmitter. The Commission will not exempt Part 15 devices from this latter requirement because of the application for which the Part 15 transmitter is employed. Thus, the Commission strongly recommends that utilities, cellular stations, public safety services, government agencies and others that employ Part 15 transmission systems to provide critical communication services should exercise due caution to determine if there are any nearby radio services that could be affected by their communications.

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[34] While the number of Part 15 operations within these bands has continued to increase, the Commission notes that Part 15 devices are not allocated spectrum within these bands but are permitted to operate on a sufferance basis. Thus, the potential for interference between Part 15 devices is not normally considered when implementing changes to the standards.

[35] *See* 47 CFR § 15.19.

[36] "Susceptibility standards" address the ability of a product, such as a digital device, to reject interference that could be caused by other nearby sources of radio frequency noise. Such standards generally are not applicable to transmitter/receiver systems. Any RF noise appearing in the passband of a receiver will be received by that system irrespective of the establishment of susceptibility standards.

[37] *See* 47 USC 302(a).

15. Finally, American Petroleum Institute (API) requests the Commission to clarify that users are permitted to increase the transmitter power or antenna gain to account for transmission line loss.[38] The Commission already permits manufacturers of systems that must use long transmission lines to measure transmitter output at the connection between the transmission line and the antenna.[39] This permission, however, is done on a case-by-case basis and must be justified during the certification procedure. Generally, the manufacturer must be able to demonstrate that the system will be professionally installed and that the design or placement of the equipment requires the use of long transmission lines. In certain cases, external radio frequency power amplifiers, as discussed below, can be incorporated as part of the system design and authorized under the certification procedure in order to offset the effect of long transmission lines. Manufacturers should note that increases to the output power of a transmitter beyond what was authorized under certification normally requires a new application for, and grant of, certification.[40] Further, the antennas employed with a spread spectrum transmitter must be certified as part of the system.[41]

2. Output power reduction in the 2400 MHz band.

16. The Commission proposed that the output power of a transmitter be decreased by 1 dB for every 3 dB that the antenna gain exceeds 6 dBi in order to maintain an "equivalent" area of interference, *i.e.*, the geographic area over which interference could result with a directional antenna as compared to the area obtained with an omnidirectional antenna.[42] Comments regarding this proposal were mixed. Adtran, API, Digital Wireless Corporation (Digital Wireless) and Rockwell International Corporation (Rockwell) support the proposed power reduction. Adtran agrees that the proposed power reduction will provide an equivalent area of potential interference between point-to-point systems using high gain antennas and systems employing an omnidirectional antenna operating at the current maximum EIRP of 6 dBW.[43] API states that it supports this method for limiting the equivalent area of interference for both the

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[38] *See* API Comments at 2.

[39] *See* also, the discussion on external radio frequency power amplifiers later in this Report and Order.

[40] *See* 47 CFR § 2.1043(a).

[41] *See* 47 CFR §§ 2.143(b) and 15.203. Manufacturers should also note that the use of an antenna other than the type with which the transmitter was certified could cause the levels of the spurious emissions, especially those emissions appearing within the restricted frequency bands described in 47 CFR § 15.205, to exceed the established limits. Additional information regarding the authorization of systems with multiple antenna configurations can be found later in this Report and Order under the discussion regarding external radio frequency power amplifiers.

[42] *See Notice* at para. 16. While this would result in a slight reduction in the effective radiated power level of the system, the higher gain employed by the antenna would still be available to concentrate the received signal.

[43] *See* Adtran Comments at 2.

2450 MHz and 5800 MHz bands.[44] Equipment manufacturers in general and many users believe that such a reduction in power is unnecessary and would restrict the use of the systems.[45] Cylink believes that the reduction in power will preclude many uses due to a loss of range and reliability and recommends letting the market forces for frequency reuse determine the technical system design decisions.[46]

17. The Commission recognizes that there is a potential that licensed services could receive harmful interference from ISM devices operating in the 2450 MHz and 5800 MHz bands. However, all radio services operating in these bands are required to accept whatever level of interference is received from ISM devices. On the other hand, Part 15 devices are secondary to all other radio operations. Accordingly, the Commission remains concerned that increases in the proliferation of high powered spread spectrum systems operating in the 2450 MHz band could exacerbate interference problems, especially to the large number of mobile licensees in the Public Safety Radio Services under Part 90 of the regulations. The upper portion of the 2450 MHz band is the only portion of the radio spectrum allocated to the Part 90 Private Land Mobile Radio Services that permits wide bandwidth mobile operation. This wide bandwidth is critical for the operation of police surveillance systems and other functions, such as video links used with bomb disposal systems. In addition, the lower portion of the 2450 MHz band is used for mobile operations by the U.S. Government and by the Amateur Radio Service under Part 97 of the rules. In addition, the Commission has already recognized the extensive applications being developed for Part 15 devices.[47] These Part 15 devices would be used for a variety of consumer and business oriented applications, including wireless LANs, automatic meter reading systems, telephones, broadband access to Internet services, video conferencing, health care monitoring, and traffic light control. In order to lower the probability of harmful interference to these operations, the Commission believes that it is necessary to implement its proposal to decrease the output power of a spread spectrum transmitter operating in the 2450 MHz band by 1 dB for every 3 dB that the antenna gain exceeds 6 dBi. This action will ensure that the area over which harmful interference can occur is equivalent to what would be caused by a spread spectrum system employing an omnidirectional antenna and operating at the current maximum EIRP of 6 dBW. While this minimal reduction in transmitter output power with the use of high gain antennas may cause some decrease in transmission range, the higher gain antenna will still provide amplification of received signals while minimizing interference potential. The Commission is not implementing its proposal to reduce the output power of a transmitter operating in the

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[44] *See* API Comments at 4, 5.

[45] *See* comments from AT&T, Columbia Gas Transmission, Cylink, Gabriel Electronics, OCOM, Oneonta Telephone, Part 15 Coalition, Questar InfoComm, Inc., Rural Cellular, Sola Communications, Inc. (Sola Communications), United States Cellular Corporation, US West, and WMC.

[46] *See* Cylink Comments at 12.

[47] *See First Report and Order and Second Notice of Proposed Rule Making*, ET Docket No. 94-32, 10 FCC Rcd 4769 (1995), at para. 32-35.

5800 MHz band. In addition to the scarcity of mobile units in the 5800 MHz band, the different propagation characteristics at 5800 MHz and the increased attenuation due to terrain and other intervening objects should be sufficient to reduce potential interference to the licensed radio services.

3. Ratio of horizontal and vertical antenna beamwidths.

18. The Commission also proposed that the 3 dB beamwidths of the high gain directional antennas employed with these fixed, point-to-point systems differ by no more than a factor of two between the vertical and the horizontal planes.[48] It indicated that this could reduce potential interference problems due to excessive emissions in the vertical or horizontal plane resulting from the antenna design. Adtran and Digital Wireless were the only parties to support the proposal, believing that it would minimize cross-interference, resulting in a "win-win" situation for point-to-point and mobile users.[49] Cushcraft, Cylink, the Part 15 Coalition and WMC believe that the requirement is an unnecessary regulation.[50] Cushcraft, an antenna manufacturer, believes that the majority of antennas already meet this criterion. Cylink opposes the proposal because it may prevent applications that require a different antenna design, such as communications to off-shore platforms. The Commission agrees with the latter commenters that this portion of its proposal is unnecessary, and it will, therefore not adopt this proposal.

4. Limitations on the operation of high gain antenna systems.

19. The Commission proposed to apply several conditions to the operation of spread spectrum systems employing high gain directional antennas.[51] First, the operation of these systems would be limited to fixed, point-to-point applications. Second, point-to-multipoint systems, omnidirectional applications and multiple co-located transmitters transmitting the same information would be prohibited. Third, the operator of a spread spectrum system would be responsible for ensuring that the system is operated in this manner.[52] Fourth, the manual supplied with the spread spectrum transmitter must contain language in the installation instructions notifying the operator of this responsibility. Fifth, the marketing of spread spectrum systems employing high gain directional antennas would be limited to commercial or industrial operators,

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[48] *See Notice* at para. 17.

[49] *See* Adtran Comments at 4; Digital Wireless Comments at 2.

[50] *See* Cushcraft Comments at 4; Cylink Comments at 13; Part 15 Coalition Comments at 4; WMC Comments at 10.

[51] *See Notice* at para. 12-13.

[52] Normally the holder of a license from the Commission is responsible for ensuring that transmitting equipment is properly used. However, under Part 15 there are no station licenses.

and sales to the general public would be prohibited.

20. Comments supporting these proposals were received from several parties, including Apple, AT&T, Columbia Gas, OCOM Corporation (OCOM), and Rockwell. Multipoint Networks, in late filed comments, requests that 5800 MHz spread spectrum transmitters be permitted for point-to-multipoint applications as long as directional antennas are employed.[53] It states that the combination of sectored antennas at a central site, along with directional antennas at remote sites, can limit the total interference potential caused by a point-to-multipoint system to levels well below the interference potential caused by the larger number of point-to-point links that would otherwise be required. Rockwell, while opposed to the use of high gain antennas in the 2450 MHz band, recommends that the installation of high gain antennas in the 5800 MHz band could be limited to the equipment authorization grantee or entities contracted by the grantee.[54] Apple asks for clarification that the restriction to commercial and industrial users does not exclude municipalities, health care and educational institutions.[55]

21. The Commission is adopting its proposals from the *Notice*. It does not agree with Multipoint Networks that point-to-multipoint applications should be permitted for systems employing high gain directional antennas with EIRPs greater than 4 watts. The use of multiple or sectored antennas to provide point-to-multipoint coverage can significantly increase the potential for harmful interference to other radio service by providing what appears, in effect, to be omnidirectional coverage but with a significant increase in EIRP. The potential for harmful interference is reduced by restricting these systems, as proposed in the *Notice*, to point-to-point applications and prohibiting point-to-multipoint systems, omnidirectional antennas or multiple co-located transmitters transmitting the same information. As proposed by the Commission in the *Notice*, the operator of the spread spectrum system or, if the equipment is professionally installed, the installer will be responsible for ensuring that the system is operated in this manner; however, the manual supplied with the spread spectrum transmitter must contain language in the installation instructions notifying the operator and the installer of this responsibility. These provisions will lower the potential for high signal level spread spectrum systems to cause harmful interference by limiting the proliferation of these systems and by strongly encouraging professional installations. The Commission no longer agrees that the regulations need to limit the marketing of 2450 MHz or 5800 MHz systems employing high gain directional antennas and high EIRPs to commercial or industrial applications or that sales to the general public need to be specifically prohibited. The use of these systems are already restricted to fixed, point-to-point applications, and the type of antennas employed generally require professional installation. These features should be sufficient to reduce the potential for harmful interference to other radio services without additional restrictions being placed on the marketing of the equipment.

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[53] *See* Multipoint Network Comments at 2. Multipoint Network's comments are being accepted as late-filed comments.

[54] *See* Rockwell Comments at 4.

[55] *See* Apple Comments at 7.

B. Minimum number of hopping channels

22. In the *Notice*, the Commission proposed to reduce the minimum number of non-contiguous channels that must be employed by a frequency hopping spread spectrum system in the 915 MHz band from 50 channels to 25 channels.[56] This reduction in the number of hopping channels would enable frequency hopping spread spectrum systems to avoid operations on frequencies used by wideband, multilateration LMS systems, reducing mutual interference problems. In order to keep the interference potential from increasing due to the reduced number of hopping channels, the Commission also proposed that frequency hopping spread spectrum transmission systems operating with less than 50 channels employ channel bandwidths of at least 250 kHz and operate at a reduced power level.[57] Further, the maximum average time of occupancy on any hopping frequency for transmitters using less than 50 hopping channels would be increased to 0.4 seconds in any 10 second period.[58]

23. The Commission requested comments as to whether the rules should specify a formula for the minimum number of hopping channels based on the amount by which the bandwidth of the hopping channel exceeds 250 kHz.[59] It stated that the use of this formula would result in an even distribution of the hopping channels over that portion of the 915 MHz band that is not employed by wideband multilateration LMS systems. This would prevent frequency hopping systems employing between 250 kHz and 500 kHz bandwidth hopping channels from being concentrated in any single portion of the 915 MHz band.

24. Because the smaller number of hopping channels would increase the potential for interference, the Commission proposed to require that frequency hopping spread spectrum systems in the 915 MHz band that use fewer than 50 hopping channels operate with a maximum peak transmitter output power of 500 mW. However, the Commission indicated that, while the potential for harmful interference can be offset by a reduction in operating power, a linear

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[56] *See Notice* at para. 30-34. The use of non-contiguous frequency hopping channels is already required under the rules. This requirement is contained in the Commission's definition of a frequency hopping system which states that the frequency of the carrier changes at fixed intervals under the direction of a pseudorandom code. *See* 47 CFR § 2.1. While the Commission also proposed to amend the definition of frequency hopping systems and pseudorandom sequence, the revised definitions would still require the use of non-contiguous channels.

[57] The maximum 20 dB bandwidth of the hopping channel would remain 500 kHz.

[58] Currently, the maximum average time of occupancy on any hopping channel in the 915 MHz band is 0.4 seconds in any 20 second period.

[59] Under this approach, the minimum number of hopping frequencies would be equal to 25 x (500/20 dB bandwidth of a single hopping channel in kHz) or 50 hopping frequencies, whichever results in the lowest number of hopping frequencies. Adopting this formula would also require that the average time of occupancy on any hopping frequency not exceed 0.4 seconds within a 20 x (number of hopping channels/50) second period.

reduction may not be sufficient to provide this offset.[60] It recognized that the chance of collisions with other transmissions, and resulting interference, would be increased since there are a fewer number of hopping channels resulting in a change to the average time of occupancy on any frequency and the crowding of transmissions into less spectrum. Accordingly, comments were requested as to whether or not a greater reduction in output power should be applied.[61] Comments were also requested on whether a limit on spectral power density, similar to that currently applied to direct sequence systems, should be applied to frequency hopping systems operating with fewer than 50 hopping channels.

25. Most of the commenting parties support the proposal to reduce the minimum number of required channels employed by frequency hopping spread spectrum systems in the 915 MHz band from 50 to 25 channels. The commenters agree that reducing the minimum number of hopping channels will help Part 15 devices to avoid frequencies used by wideband multilateration LMS systems. Ericsson Corporation (Ericsson) and Teletrac License, Inc. (Teletrac) request further restrictions to require frequency hopping systems using less than 50 channels to avoid using LMS spectrum.[62] Teletrac proposes that frequency hopping systems using fewer than 50 channels be restricted from using the LMS sub-bands to occupy more than 50 percent of their needed bandwidth.[63] Teletrac adds that frequency hopping spread spectrum systems that employ at least 50 hopping channels should continue to be presumed not to be a source of harmful interference to multilateration LMS systems, but that this presumption should not apply to systems that employ less than 50 hopping channels and use any channels in the multilateration LMS bands.[64] Digital Wireless strongly opposes Teletrac's proposal, stating that frequency hopping systems should not be restricted from using spectrum in areas where there are no LMS users or only partial use of the spectrum by LMS systems.[65] The International Microwave Power Institute (IMPI) is the only party to oppose a reduction in the number of channels because it is concerned that frequency hopping systems operating in a narrower band may be more susceptible

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[60] The reference to a linear power reduction means that the maximum output power is reduced by the same percentage as the reduction in the number of hopping channels. For example, if the number of hopping channels is reduced by 50 percent, *i.e.*, to 25 hopping channels, the maximum output power is also reduced by 50 percent, *i.e.*, to 500 mW. This is the amount of reduction requested by SpectraLink in its petition.

[61] The Commission also requested comments on whether a power reduction based on the actual number of hopping channels should be employed. If a linear reduction was to be employed, this would result in a maximum peak transmitter output power of no greater than (number of hopping channels/50) watts or one watt, whichever is the lesser power.

[62] *See* Ericsson Comments at 3; Teletrac Comments at 5.

[63] *See* Teletrac Comments at 6.

[64] *See* 47 CFR § 90.357(a).

[65] *See* Digital Wireless Reply Comments at 1.

to interference from ISM devices.[66]

26. Apple, Digital Wireless and SpectraLink support the adoption of simple, unambiguous rules rather than limits based on a complex formula.[67] While the commenting parties also support a reduction in power for systems using fewer than 50 channels, the comments vary on the appropriate method and level of reduction. Adtran, Itron, Inc. (Itron), the Part 15 Coalition and SpectraLink support adoption of the proposed 500 mW limit.[68] Ericsson believes that the power limit should be reduced to 100 mW rather than 500 mW.[69] Metricom recommends adopting a 250 mW output limit.[70] Rockwell and Telecommunications Industry Association, Wireless Consumer Communications Section (TIA Wireless) recommend using formulas that relate the power limit to the number of hopping channels.[71] TIA Wireless submitted the only detailed technical analysis relating the interference potential of a frequency hopping system to the number of hopping channels and the transmitter output power. The formula developed by TIA Wireless indicates that a frequency hopping system using 25 hopping channels should have a transmitter output limit of 250 mW in order for the interference potential to be no greater than that of a 50 channel system operating with a transmitter output power of 1 W.[72] RAMAR Technology, Ltd. (RAMAR) believes a power density limit should be applied to frequency hopping transmitters.[73]

27. The Commission agrees with the comments that the minimum number of hopping channels for spread spectrum systems operating in the 915 MHz band should be reduced from 50 to 25 channels for frequency hopping systems employing hopping channels bandwidths of at

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[66] *See* IMPI Comments at 2.

[67] *See* Apple Comments at 4; Digital Wireless Reply Comments at 3; SpectraLink Comments at 5.

[68] *See* Adtran Comments at 4; Itron Comments at 2; Part 15 Coalition Comments at 6; SpectraLink Comments at 3.

[69] *See* Ericsson Comments at 3. Additionally, Ericsson is concerned that frequency hopping systems operating in a narrower bandwidth will adversely impact other Part 15 devices operating under Section 15.249 and requests an increase in power for these devices. This request is outside the scope of this proceeding and will not be considered herein.

[70] *See* Metricom Reply Comments at 3.

[71] *See* Rockwell Comments at 7; TIA Wireless Comments at 2-5.

[72] *See* TIA Wireless Comments, Attachment at 1. The formula developed by TIA Wireless states "[f]or frequency hopping systems operating in the 902-928 MHz band: 1 watt for systems employing at least 50 hopping channels. For systems employing less than 50 hopping channels, the lesser of: (1) $(n \cdot \Delta f/26)^2$ watts, and (2) $(m/50)^2$ watts; where n is the total number of system-defined channels from which the actual hopping channels are randomly-selected, Δf is the minimum center frequency separation between any two of the system-defined channels, in MHz, and m is the number of hopping channels employed."

[73] *See* RAMAR Comments at 4.

least 250 kHz.[74] A corresponding change to the average time of occupancy on any hopping frequency, as proposed in the *Notice*, is also being adopted to accommodate the smaller number of hopping channels. Adoption of these proposals will allow a reduction, from 25 MHz to 12.5 MHz, in the spectral occupancy of frequency hopping spread spectrum systems operating at the maximum channel bandwidth.[75] By decreasing the number of frequency hops, the users of Part 15 spread spectrum systems can avoid operating in the frequency bands employed by wideband multilateration LMS systems and, thereby, reduce mutual interference problems.[76] Part 15 spread spectrum transmitters operating in the 915 MHz band under certain, specified conditions already are presumed not to be a source of harmful interference to wideband multilateration LMS systems[77]; however, it is to the benefit of the spread spectrum operators to avoid using the wideband multilateration LMS channels in order to reduce the potential for received interference. The resulting reduction in the spectral occupancy of the wideband multilateration LMS channels by spread spectrum systems will maximize spectral efficiency by increasing the number of Part 15 devices and LMS users that can coexist in the band. This should facilitate the future deployment of frequency hopping systems in the 915 MHz band.

28. The Commission does not agree with Teletrac that limitations should be placed on spread spectrum signals occupying the LMS sub-bands. As stated by Digital Wireless, there are areas within the U.S. where the wideband multilateration LMS channels are not being used or are only partially used. Further, as indicated above, Part 15 spread spectrum transmitters complying with the conditions in Section 90.361 of the rules are already presumed not to be a source of harmful interference to wideband multilateration LMS systems. Accordingly, there is no basis for prohibiting the operation of spread spectrum systems in the wideband multilateration LMS channels. It is, however, to the benefit of the spread spectrum operator to avoid operating on these LMS channels, as indicated above.

29. The Commission agrees with the comments that simple, unambiguous rules, rather than several different limits based on formulas, are appropriate, and is so amending its regulations. The Commission also agrees with the technical analysis presented by TIA Wireless that the peak output power of a spread spectrum transmitter operating with less than 50 hopping

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[74] Frequency hopping spread spectrum systems employing channel bandwidths less than 250 kHz can already avoid using the spectrum allocated for wideband multilateration LMS systems.

[75] A total of 26 MHz of spectrum is available for spread spectrum systems operating in the 915 MHz band.

[76] Wideband multilateration LMS systems operate, on a primary basis to non-multilateration systems, in the 904-909.75 MHz and 921.75-927.25 MHz bands with associated forward links in the bands 927.75-928 MHz and 927.25-927.5 MHz, respectively. This leaves only 14.25 MHz in the 915 MHz band in which frequency hopping spread spectrum systems can avoid wideband multilateration LMS systems. However, multilateration LMS systems may also operate on a co-equal basis with non-multilateration LMS systems in the band 919.75-921.75 MHz with a forward link at 927.5-927.75 MHz, or aggregate operation to include the 921.75-927.25 MHz band, leaving only 12 MHz of available spectrum. *See* 47 CFR § 90.357(a).

[77] *See* 47 CFR § 90.361.

channels should be reduced to 250 mW with a maximum directional antenna gain of 6 dBi. As shown by TIA Wireless, this change is necessary to avoid increasing the interference potential of frequency hopping spread spectrum systems operating with a reduced number of hopping channels. Accordingly, the regulations are being amended to adopt a peak transmitter output limit of 250 mW for frequency hopping spread spectrum systems operating with less than 50 hopping channels.

30. Finally, the Commission noted that a number of petitions for reconsideration had been received in response to the recent *Report and Order* implementing the LMS systems.[78] It indicated that any changes to the LMS rules in response to those petitions could result in modifications to the amendments that were proposed in the *Notice* for Part 15 spread spectrum operation in the 915 MHz band. Adtran, Lucent Technologies Inc. (Lucent), Metricom, the Part 15 Coalition and TIA Wireless oppose any changes to Part 15 rules in this proceeding based on changes made to the LMS regulations.[79] Lucent states that there is no need to link Part 15 rules with LMS rules. Metricom and the Part 15 Coalition state that parties must be given an opportunity to make comments under the Administrative Procedure Act and that no changes to the spread spectrum rules based on changes to the LMS regulations should be made without a new rule making. The Commission concurs with the comments that these changes to the regulations should not be linked to future possible changes to the LMS regulations under Part 90 of the rules.

C. Additional issues

31. The *Notice* contained several additional proposals to clarify, codify or amend the regulations concerning Part 15 spread spectrum transmission systems. These are discussed below.

1. Spectral power density.

32. When the rules for direct sequence systems were modified in 1990, a specification was added for maximum spectral power density. As stated in the 1990 *Report and Order*, the standard on spectral power density was intended to ensure that the transmitted energy is uniformly spread over the minimum channel bandwidth of 500 kHz in order to limit interference to other systems in this band.[80] At the maximum output power level of one watt, this equates to a limit of 8 dBm in any 3 kHz band. However, the one watt output power on which the limit on spectral power density is based is a peak limit, whereas the spectral power density standard

[78] *See Report and Order* in PR Docket No. 93-61, 10 FCC Rcd 4695 (1995).

[79] *See* Adtran Reply Comments at 2; Lucent Comments at 3; Metricom Comments at 7-8; Part 15 Coalition Comments at 7; TIA Wireless Comments at 5.

[80] *See Report and Order*, GEN Docket No. 89-354, 5 FCC Rcd. 4123 (1990) at para. 12.

was incorrectly stated in the rules as an average limit. Accordingly, the Commission proposed to change the reference in the rules to the maximum spectral power density from an average limit to a peak limit.[81] The measurement procedure was further described in Appendix C of the *Notice*.[82]

33. In their comments, Adtran and Digital Wireless indicated that changing the rule to specify a peak spectral power density limit might be in conflict with the reference in Appendix C of the *Notice* to the noise density function as an acceptable means of measuring systems with no resolvable spectral lines.[83] They support using the noise density function but recommend further clarification to avoid confusion. Rockwell agrees with the Commission's reasons for imposing a power spectral density limit but believes there are problems with using a peak limit.[84] It proposes using an 8 dBm RMS limit and proposes a measurement procedure using the spectrum analyzer noise density function. Rockwell also notes that there is in error in the correction factor applied for the measurement of noise density function.[85]

34. The Commission is adopting its proposal to specify the limit on spectral power density as a peak limit. It does not agree with the comments that there is a conflict with the noise density measurement nor does it agree with Rockwell that the rules should specify a limit on spectral power density of 8 dBm RMS. On the first issue, the spectral power density is normally measured with the analyzer bandwidth setting adjusted to permit resolution of the individual spectral components. With such a measurement, the peak levels being measured are the same as average measurements. The noise density is measured only during the infrequent occurrence when the individual spectral components can not be resolved. Under this specific test condition, the Commission recognizes that no instrumentation is available that is capable of measuring peak noise. Thus, an average measurement must be accepted, but only under this extenuating circumstance. With regard to Rockwell's concern, measurements obtained from a spectrum analyzer operating in the peak detection mode are in reality the RMS measurements sought by Rockwell. The specification in the rules of a peak limit, combined with the measurement procedure in Appendix C, merely ensures that parties making these measurements do not further average the obtained measurements.

35. The Commission notes that all spread spectrum transmitters previously authorized comply with the peak spectral power density limit being adopted and that this change to the rules

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[81] *See Notice* at para. 36.

[82] *See Notice* at Appendix C. These measurement procedures were released by the Commission on July 12, 1995, as a Public Notice and are also contained in Appendix C of this Report and Order.

[83] *See* Adtran Comments at 5; Digital Wireless Comments at 2.

[84] *See* Rockwell Comments at 7.

[85] *See* Rockwell Comments at Appendix B.

should not impact any systems. The Commission is also correcting the error in the measurement procedure for direct sequence systems, as shown in Appendix C. The current procedure states that, when measuring spectral power density where the spectrum line spacing can not be resolved, the noise density function on most modern conventional spectrum analyzers will directly measure the noise power density normalized to a 1 Hz noise power bandwidth. If further states that 30 dB should be added for correction to a 3 kHz bandwidth. The proper correction factor is 10 * log (3 kHz/1 Hz) dB which equals 34.8 dB.

2. Definition of direct sequence.

36. The definition of direct sequence spread spectrum systems contained in the rules has become outdated.[86] For example, the incoming information is always digitized but is not necessarily modulo 2 added to the higher speed code (spreading) sequence. The Commission proposed to amend the existing definition to simplify it and to make it more compatible with existing product designs.[87] The definition proposed in the *Notice* was: "a spread spectrum system in which the carrier has been modulated by a high speed spread code and an information data stream. The high speed code sequence dominates the 'modulating function' and is the direct cause of the wide spreading of the transmitted signal." Comments in support of this new definition were received from Adtran, Apple, and Rockwell.[88] Rockwell requests that language be added to ensure the independence of the high speed spreading code from the modulation technique, such as TDMA or FDMA. Rockwell believes that such language would ensure that systems do not partially rely on the modulation of the data stream to meet the processing gain requirement.

37. The Commission does not agree with Rockwell that the definition needs to be modified to ensure that the ability to meet the processing gain requirement does not encompass a modulation technique applied to the data stream. The definition already states that the spreading code, and not the modulation applied to the data stream, is directly responsible for the wide spreading of the transmitted signal. Further, the processing gain is determined based on the ratio of the signal-to-noise of the received signal both with and without the spreading code applied. Thus, the modulation technique applied to the data stream should not affect the measured processing gain. Accordingly, the Commission is adopting the definition proposed in

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[86] Currently, a direct sequence system is defined as "...a spread spectrum system in which the incoming information is usually digitized, if it is not already in a binary format, and modulo 2 added to a higher speed code sequence. The combined information and code are then used to modulate a RF carrier. Since the high speed code sequence dominates the modulating function, it is the direct cause of the wide spreading of the transmitted signal." *See* 47 CFR § 2.1. Modulo 2 addition is a form of binary addition for adding two binary data streams to produce a third. When both data streams are in the "zero" or "one" state simultaneously, the result is a zero;" when each of the data streams are in the opposite states, the result is a "one."

[87] *See Notice* at para. 37.

[88] *See* Adtran Comments at 5; Apple Comments at 10; Rockwell Comments at 8.

the *Notice*.

3. Definition of pseudorandom sequence and frequency hopping systems.

38. The current definition of a pseudorandom sequence is used to establish standards for frequency hopping systems.[89] However, the wording of this definition has caused considerable confusion in industry as to exactly how a frequency hopping system must be designed to ensure that the system meets the pseudorandom sequence definition. In the *Notice*, the Commission proposed to simplify the standards by eliminating the definition of pseudorandom sequence and by amending the definition of frequency hopping systems to include a simple description of the required hopping sequence.[90] The definition of a frequency hopping system proposed in the *Notice* was: "a spread spectrum system in which the carrier is modulated with the coded information in a conventional manner causing a conventional spreading of the RF energy about the frequency carrier. The frequency of the carrier is not fixed but changes at fixed intervals under the direction of a coded sequence. The wide RF bandwidth needed by such a system is not required by spreading the RF energy about the carrier but rather to accommodate the range of frequencies to which the carrier frequency can hop. The test of a frequency hopping system is that the near term distribution of hops appears random, the long term distribution appears evenly distributed over the hop set, and sequential hops are randomly distributed in both direction and magnitude of change in the hop set." General supporting comments for this new definition were received from Adtran and Apple.[91] The Commission agrees with the comments and is adopting this change to the rules, as proposed in the *Notice*.

[89] A pseudorandom sequence currently is defined as "[a] sequence of binary data which has some of the characteristics of a random sequence but also has some characteristics which are not random. It resembles a true random sequence in that the one bits and zero bits of the sequence are distributed randomly throughout every length, N, of the sequence and the total numbers of the one and zero bits in that length are approximately equal. It is not a true random sequence, however, because it consists of a fixed number (or length) of coded bits which repeats itself exactly whenever that length is exceeded, and because it is generated by a fixed algorithm from some fixed initial state." A frequency hopping system currently is defined as "...a spread spectrum system in which the carrier is modulated with the coded information in a conventional manner causing a conventional spreading of the RF energy about the carrier frequency. However, the frequency of the carrier is not fixed but changes at fixed intervals under the direction of a pseudorandom coded sequence. The wide RF bandwidth needed by such a system is not required by a spread of the RF energy about the carrier but rather to accommodate the range of frequencies to which the carrier frequency can hop." *See* 47 CFR § 2.1.

[90] *See Notice* at para. 38.

[91] *See* Adtran Comments at 5; Apple Comments at 10.

4. Short duration transmissions.

39. As indicated in the *Notice*, the Commission has received a number of applications for frequency hopping systems that transmit only for short periods of time.[92] Most of these systems can transmit all necessary information using a single transmission, *i.e.*, without the need to hop to a second frequency. These applicants request inclusion under the spread spectrum rules in order to be allowed to use transmitters with an output power of one watt.

40. The current rules and definitions require that a spread spectrum system, consisting of both the transmitter and the receiver, must be designed to act as a frequency hopping system, should the transmitter be presented with a data stream longer than that which could be completed in a single hop.[93] The Commission proposed to leave these criteria intact, requiring that products being authorized as frequency hopping systems be capable of acting as frequency hopping systems. However, it requested comments on these issues and indicated that it would consider proposals for alternative approaches to the existing regulations that would facilitate or prohibit the operation of short duration transmission systems under the spread spectrum frequency hopping regulations.

41. Many of the commenting parties, including API, Cylink, Master Lock Company (Master Lock) and Metricom, recommend that the Commission retain the requirement that frequency hopping systems must be capable of hopping.[94] API states that maintaining the requirement that systems authorized as frequency hoppers actually be capable of hopping will prevent the proliferation of technically-inferior, single frequency radios. Metricom states that short hop systems must comply with Section 15.247 rules or else they could cause problems with spread spectrum systems. However, it also believes that systems employing short duration transmissions that are capable of hopping should not be precluded.

42. Itron supports permitting short duration systems and recommends eliminating the requirement for transmitter/receiver hopping channel synchronization for systems with channel occupancy of less than 400 ms.[95] The Itron meter-reading system uses a bank of parallel

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[92] *See Notice* at para. 39-40.

[93] Systems requiring short duration transmission bursts are specifically accommodated under different regulations, although at lower power levels. *See, e.g.*, 47 CFR §§ 15.231(e) and 15.249.

[94] *See* API Comments at 6; Cylink Comments at 13; Master Lock Comments at 2; Metricom Comments at 7. In addition, Alliant Techsystems, Inc. (Alliant) supports permitting non-spread spectrum devices to use one watt of power for short duration transmissions for certain public safety related applications. *See* Alliant Comments at 3. RAMAR also believes that the power levels under § 15.231(e) overcompensates for the need to minimize potential interference and recommends using an average power limit over one second instead of the current peak limit. *See* RAMAR Comments at 2. Alliant's and RAMAR's comments deal with short duration systems operating under 47 CFR § 15.231 of the rules and are beyond the scope of this proceeding.

[95] *See* Itron Comments at 4-5.

receivers that detect messages transmitted from the meters being read. Further, Itron recommends that there be no minimum requirement on the number of frequency hops during any one transmission, provided that there is a minimum of 25 or 50 total hopping frequencies in the system, the minimum channel spacing requirements are maintained, and the transmitter utilizes all frequencies in a pseudorandom sequence uniformly over time. CellNet Data Systems (CellNet) recommends retaining a requirement for transmitter and receiver synchronization.[96] Alternatively, CellNet and the Part 15 Coalition[97] support the use of a parallel receiver architecture, as proposed by Itron, but maintain that the transmitter and receiver should have the same number of channels and the same bandwidth. Lucent believes that it is unnecessary to change the rules at this time to permit short duration systems.[98] It states that there are only a limited number of proposed systems at this time and that they should be addressed individually under the waiver process.

43. As stated in the *Notice*,[99] a frequency hopping system only exhibits the characteristics of a spread spectrum system, *i.e.*, a low propensity to cause interference and a relatively high tolerance of interference from other sources, when it hops to multiple channels. Consequently, a transmission that does not hop also does not exhibit any of the characteristics of a spread spectrum system, *e.g.*, processing gain exhibited by the receiver. Thus, absent processing gain, a system employing short transmission bursts must transmit at higher power levels than would be required by a spread spectrum system, increasing the potential for harmful interference to other users. Because of this risk of increased interference, the Commission sees no justification at this time for permitting the higher power levels currently available for spread spectrum systems to be employed by systems that do not employ spread spectrum modulation techniques. The Commission is, however, amending the regulations to clarify that short duration transmission systems are permitted provided the systems are capable of complying with all of the standards should the system be presented with a continuous data or information stream. This equipment, when operating with the short transmission bursts, must also comply with the definition of a frequency hopping system and must distribute its transmissions over the minimum number of hopping channels specified in the regulations.

5. Measurement of processing gain.

44. Under the rules, direct sequence systems are required to exhibit a processing gain of at least 10 dB. This processing gain is determined from the ratio in dB of the signal-to-noise ratio with the system spreading code turned off and the signal to noise ratio with the system

[96] *See* CellNet Data Reply Comments at 7.

[97] *See* Part 15 Coalition Comments at 6.

[98] *See* Lucent Reply Comments at 5.

[99] *See Notice* at para. 39.

spreading code turned on, as measured at the demodulated output of the receiver. The standard for a minimum processing gain was established to ensure that a system is, in fact, spread spectrum in nature. Absent this standard, there is a strong potential for abuse of the Part 15 spread spectrum provisions.[100] However, in the *Notice* the Commission noted that this method of measurement does not always work since many equipment designs do not provide an ability to turn off the system spreading code.[101] In these cases, an indirect measurement of processing gain, based on the receiver jamming margin, is permitted.[102] Some manufacturers have indicated that processing gain could be based on the ratio of the chipping (spreading) rate to data rate; however, this method would calculate the maximum possible gain assuming a perfect receiver, whereas the actual gain achieved may be significantly less. The actual processing gain is dependent on the design of the complete spread spectrum system, including the receiver. For this reason, the Commission believes it is necessary to require a demonstration of the improvement in received signal-to-noise ratio produced by the spreading/despreading process. Thus, in the *Notice* the Commission proposed to incorporate the measurement procedure shown in Appendix C into the regulations to provide an alternative method of measuring processing gain. Interested parties were invited to comment on this proposal and to submit suggestions for alternative methods of measuring the processing gain of the complete spread spectrum system.

45. General comments supporting the proposal to incorporate into the rules an alternative method of measuring processing gain were received from Adtran, Apple, Digital Wireless, Microwave Data Systems (MDS), and the Part 15 Coalition.[103] Adtran and Digital Wireless believe the two alternative procedures contained in the *Notice* are nearly equivalent and will preclude the approval of non-compliant systems. The Commission agrees with these comments and is amending the rules, as proposed.

6. Limits on unwanted emissions.

46. The current regulations require that all spurious emissions outside of the frequency band employed by the spread spectrum transmitter be attenuated as follows: 20 dB for emissions produced by the modulation products of the spreading sequence, the information sequence, and the carrier; and, the general limits in 47 CFR Section 15.209 for all other emissions. This regulation has caused some confusion to equipment manufacturers regarding the proper

[100] *See Report and Order*, GEN Docket No. 89-354, *supra*, at para. 13-17.

[101] *See Notice* at para. 41.

[102] The "receiver jamming margin" is representative of the ability of the receiver to reject other radio signals appearing on the same frequency. An explanation of this measurement procedure, along with other measurement procedures currently employed for direct sequence spread spectrum systems, is presented in Appendix C.

[103] *See* Adtran Comments at 6; Apple Comments at 10; Digital Wireless Comments at 2; MDS Comments at 3; Part 15 Coalition Comments at 6.

attenuation limits for specific spurious signals and whether these limits are based on radiated emissions or emissions conducted to the antenna. In addition, many applicants appear to be unaware that the attenuation requirements for emissions appearing in the restricted bands also apply to spread spectrum transmitters.[104] Thus, in the *Notice* the Commission proposed to simplify the existing standards by stating that all emissions outside of the frequency band employed by the spread spectrum transmitter, except for emissions within the restricted bands, must be attenuated by at least 20 dB.[105] It further proposed to clarify these requirements by stating that demonstration of compliance with this 20 dB emission standard can be based on RF antenna conducted or radiated measurements. Finally, it proposed to reference in the spread spectrum rules the requirements for the attenuation of radiated emissions in the restricted bands. Since the limits for emissions appearing in the restricted bands are expressed in terms of the field strength of the signals, emission levels in these bands must always be determined based on radiated emission measurements.

47. The comments from Adtran, Apple, Digital Wireless, MDS, and the Part 15 Coalition supported the proposal in the *Notice*.[106] The Commission received no opposition to this proposal. It agrees with the comments and believes that this change to the regulations will provide needed simplification and clarification to the rules. Accordingly, the Commission is adopting the changes to the regulations, as proposed.

7. Frequency hopping coordination.

48. Prior to issuance of the *Notice*, several manufacturers requested authorization of frequency hopping systems that contain intelligence to recognize other users within the spectrum band and avoid hopping on occupied channels. Under the current rules, coordination between hopping transmitters is not normally permitted since this would easily allow an operator of multiple transmitters to monopolize the spectrum in a given location.[107] Further, the resulting

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[104] *See* 47 CFR § 15.205.

[105] *See Notice* at para. 41.

[106] *See* Adtran Comments at 6; Apple Comments at 10; Digital Wireless Comments at 3; MDS Comments at 3; Part 15 Coalition Comments at 6.

[107] Frequency hopping spread spectrum systems must hop to frequencies that are selected from a pseudorandomly ordered list of frequencies. *See* 47 CFR §§ 2.1 and 15.247(a)(1). The prohibition against coordination is also stipulated in the grant of certification issued to each frequency hopping spread spectrum transmitter under note code 47: "This grant is issued subject to the condition that the transmitter covered hereunder will not be marketed with any capability to coordinate its hopping sequence with the hopping sequence of other transmitters, or vice versa, for the purpose of avoiding the simultaneous occupancy of individual hopping frequencies by multiple transmitters." An example of the problem that could occur from coordinated frequency hopping transmitters is as follows: if 50 frequency hopping spread spectrum system transmitters located in the same general vicinity and operating with 500 kHz channels in the 915 MHz band were permitted to coordinate hopping channels,