Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D. C. 20554

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

NOTICE OF PROPOSED RULE MAKING

Adopted: January 30, 1996 ; Released: February 5, 1996

Comment Date: [75 days from date of publication in the Federal Register]
Reply Comment Date: [105 days from date of publication in the Federal Register]

By the Commission:

INTRODUCTION

By this action, the Commission proposes to amend Parts 2 and 15 of the 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, we are proposing to eliminate the limit on directional gain antennas for spread spectrum transmitters operating in the 5800 MHz band. We are also proposing to reduce, from 50 to 25, the minimum number of channels required for frequency hopping spread spectrum systems operating in the 915 MHz band. These proposals are in response to Petitions for Rule Making filed by Western Multiplex Corporation (WMC) and SpectraLink Corporation (SpectraLink), respectively. We also are denying a Petition for Rule Making from Symbol Technologies, Inc. (Symbol) that seeks a reduction in the minimum number of required hopping channels, from 75 to 20, for frequency hopping spread spectrum systems operating in the 2450 MHz and 5800 MHz bands. On our own motion, we are proposing 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. The changes will expand the ability of equipment manufacturers to develop spread spectrum systems for unlicensed use.

BACKGROUND

Part 15 of the regulations permits the operation of radio frequency devices without a license from the Commission or the need for frequency coordination.[2] The technical standards

1 For simplicity, these bands will be referenced in this proposal as 915 MHz, 2450 MHz and 5800 MHz, respectively.

2 See 47 CFR Section 15.1 et seq.

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. The spreading technique used in the transmitter is duplicated in the receiver to enable detection and decoding of the signal. 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. In addition, the signal processing tends to suppress undesired signals, enabling these systems to tolerate strong interference.[5]

4. 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 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.

5. The existing regulations limit spread spectrum systems to a maximum peak transmitter output power of one watt.[6] 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. Direct sequence systems must employ a minimum 6 dB 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 20 dB 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 20 dB channel bandwidth of 1 MHz.

PETITIONS FOR RULE MAKING

Western Multiplex Corporation (WMC)

6. The Petition. WMC filed a combined Petition for Rule Making and Request for Immediate Waiver with the Commission.[7] It requests that the limits on antenna gain be removed for spread spectrum systems operating in

[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, even to another Part 15 device, the operator is required to immediately correct the interference problem, even if correction of the problem requires ceasing operation of the system causing the interference. See 47 CFR Section 15.5.

[5] The improvement in the signal-to-noise ratio is termed "processing gain."

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

[7] See RM-8435.

the 2450 MHz and 5800 MHz bands. WMC also requests a waiver of this regulation pending consideration of the Petition for Rule Making by the Commission.[8] In its petition and comments, WMC indicates that spread spectrum systems employing antennas with levels of gain higher than that permitted under the current rules are being used to provide 1.5 Mbps T1-type links without having to go through a frequency coordination and licensing process.[9] It states that this enables rapid setup of the system and reduces costs to the user. WMC states that typical users include manufacturing and service companies, oil and gas pipeline companies, mobile and SMR operators, common carriers, public safety services, state and local governments and the U.S. Government. WMC states that typical applications include communications to oil platforms, emergency restoration of communications in disaster situations, low density spurs off microwave fiber optic backbone systems to serve remote field offices and service centers, extensions of local area networks, law enforcement and fire prevention communications, transmission of supervisory control and data acquisition circuits, seismic monitoring equipment transmissions, data transmissions, remote control of stacker reclaimer equipment, power plant control yard communications, and connections of mobile radio cell sites to the main telephone switching site. WMC argues that there are no known cases of harmful interference involving these transmitters operating with higher antenna gains. As stated by WMC, the use of directional (high gain) antennas, because of the line of sight propagation characteristics above 2 GHz, permits greater reuse of frequencies in an given area and yields a significantly higher transmission capacity per unit bandwidth than can be achieved using non-directional (low gain) antennas.[10]

7. Most of the commenting parties support WMC's request. Two parties, Alcatel Network Systems, Inc., (Alcatel) and WINDATA, Inc., (WINDATA), oppose this request.[11] Alcatel states that the WMC proposal could have the effect of reallocating the 2450 MHz and 5800 MHz bands for point-to-point use by unlicensed devices, whereas these bands could be used more efficiently by licensed microwave systems. WINDATA states that the use of higher gain antennas could result in unacceptable interference, especially to indoor Part 15 spread spectrum systems, such as wireless local area networks, that could be in the main beam of a WMC system.

8. Cylink Corp., Metricom, Inc., and Tetherless Access Ltd. filed comments requesting that the limit on maximum directional antenna gain also be deleted for systems in the 915 MHz band. This request was opposed by Pinpoint Communications, Inc., which expresses concern for potential interference by spread spectrum systems to

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[8] The current spread spectrum regulations, including the limit on the maximum directional antenna gain, apply to all equipment manufactured on or after June 23, 1994. See 47 CFR Section 15.37(a). Waivers were granted to WMC on October 3, 1994, and February 14, 1995, to Cylink Corporation on December 16, 1994, and to Atlantic Communications Sciences on February 15, 1995. These waivers extended the transition provisions relating to antenna gain for a period of two years. The spread spectrum equipment was required to meet all other standards contained in the current regulations. Further, the waivers were limited to equipment used for fixed point-to-point operations. Point-to-multipoint and omnidirectional operations were prohibited under these waivers.

[9] Under the regulations in effect for Part 15 spread spectrum equipment manufactured prior to June 23, 1994, there was no limit on the amount of antenna gain. As noted above, spread spectrum transmitters operating under Part 15 are limited to an maximum peak output level of one watt. Under WMC's request, it is conceivable that directional antenna gains of 30 dB, or greater, could be employed with these transmitters, producing effective radiated power levels in excess of 1000 watts and transmission ranges in excess of 20 km.

[10] A high gain 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.

[11] In addition, Cornell University expressed concern about potential high level emissions that could occur in the 2370-2390 MHz band which is used for planetary radar studies. However, this is a restricted band, and the emission levels produced in this band are stringently controlled, regardless of the total effective radiated power of the spread spectrum transmitter. See 47 CFR Section 15.205.

its automatic vehicle monitoring system/location monitoring service operating in the same band under Part 90 of our regulations.

9. Discussion. We recognize 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 frequency coordination and licensing. The ability to establish such transmission links quickly could be critical in emergency situations. However, because the use of high power radio links without prior frequency coordination could result in significant interference problems to other operators using these frequency bands, we believe it is necessary to restrict their use. The frequency bands addressed in the WMC petition are allocated for operation by industrial, scientific and medical devices, U.S. Government stations, the Amateur Radio Service, the Private Land Mobile Radio Services, the Private Operational-Fixed Microwave Services, and Television Broadcast Auxiliary Stations. The other spread spectrum band, the 915 MHz band, is allocated for operation by industrial, scientific and medical devices, the Private Land Mobile Radio Services, and the Amateur Radio Service. Accordingly, we are proposing to eliminate the antenna directional gain limit only for non-consumer, fixed, point-to-point spread spectrum systems operating in the 5800 MHz band.

10. The spread spectrum rules, as originally adopted, did not specify a limit on antenna gain. At that time, there were few other operators in these bands and little potential that interference would be caused to other users. Further, we wished to offer an incentive to spur the development of spread spectrum systems. These bands, especially the 915 MHz and the 2450 MHz bands, are now becoming more crowded, particularly with mobile units, increasing the potential that spread spectrum systems using high gain antennas will cause harmful interference. In addition to the licensed radio services, wireless computer local area network systems and various consumer products, such as cordless telephones, are being used under Part 15 in the 915 MHz and 2450 MHz bands.

11. However, as there are few operators in the 5800 MHz band, the potential that harmful interference will occur from the use of directional antennas is much lower. There are also fewer mobile users in the 5800 MHz band. It is easier to engineer a fixed, point-to-point system to operate without causing harmful interference problems if the other stations in that band are fixed in location. Further, the 5800 MHz band is ideal for fixed, point-to-point wideband microwave operations, the type of applications desired by WMC. Accordingly, we believe the limit on directional antenna gain should only be eliminated for spread spectrum systems operating in the 5800 MHz band. We request comment on this proposal. While we are not inclined to provide a similar relaxation for the 2450 MHz band, we also ask for comment on whether we should eliminate the 6 dB limit on directional antenna gain in this band.

12. While the use of high gain directional antennas can reduce the potential for interference to radio operations located outside the directional beam of the antenna pattern, the potential for harmful interference to radio systems located in the beam of the directional antenna increases significantly. Obviously, if multiple antennas are employed, providing point-to-multipoint or omnidirectional operation, the coverage area increases, but so does the potential for harmful interference. In addition, we recognize that the use of high gain directional antennas benefits primarily fixed applications. Therefore, we also believe that the restriction on directional antenna gain should be eliminated only for those 5800 MHz systems used for fixed, point-to-point operations. This proposal would not eliminate the limit on antenna gain for point-to-multipoint or omnidirectional systems, transmitters employing multiple directional antennas, or multiple co-located transmitters transmitting the same information.

13. We further believe that if spread spectrum transmitters employing high gain antennas were made available to the general public, it would be difficult to ensure that these systems are used only for fixed, point-to-point applications. In addition, high gain directional antenna systems, because of their narrow transmission beamwidth and the problems associated with aligning the transmitter with the receiver site, are not products that would normally be employed by the general public. Further, as indicated by WMC and the supporting comments, these high gain transmission systems are being employed by commercial and industrial operators for communication back-haul systems in order to avoid the expenses and delays associated with licensed systems. Accordingly, we believe that the marketing of spread spectrum systems employing high gain antennas should be limited to commercial or industrial operators and exclude sales to the general public. We further propose to hold the

operator of a spread spectrum system responsible for ensuring that the system is operated in a compliant manner.[12] In addition, we propose to require that the manual supplied with the spread spectrum transmitter contain language in the installation instructions notifying the operator of this responsibility. Commenting parties should note that the transmitter must be authorized under our certification procedure along with the specific antenna with which it will be used.[13] These components are authorized as a system to ensure that the emission limits, especially those limits designed to protect other sensitive radio services or services used for safety-of-life applications, are not exceeded.[14]

14. Absent controls regarding the locations and manner in which spread spectrum transmitters may be used, systems employing high gain directional antennas could expose the public to potentially harmful signal levels that exceed the radio frequency exposure limits of our rules and recommended by various standards-setting organizations.[15] In order to meet our obligation under the National Environmental Policy Act, we propose to hold the holder of the grant of certification for the transmitter, the grantee, responsible for ensuring that the equipment is designed to minimize exposure of the public to excessive radio frequency (RF) signal levels.[16] While we proposed to make the operator responsible for ensuring that the system is used only for fixed, point-to-point applications, the means to prevent excessive exposure levels can be incorporated into the equipment design. In addition, absent some action by the grantee to incorporate a warning into the equipment, the operator would not necessarily realize that there was a potential for excessive RF exposure levels. A possible method is a sign, attached to the antenna and of sufficient size and visibility, warning the public of the potential danger of RF exposure. Another possible method is the incorporation of proximity sensors that cause the transmitter to automatically decrease output power if someone wanders too close to the transmitting antenna. Comments are requested concerning possible biological hazards from the high effective radiated power levels that could be emitted from these systems, any additional methods that can be employed to prevent unnecessary exposure of the public, and whether we should prescribe the use of specific means for preventing such exposure.

15. Commenting parties should note that informal comments raising concerns with the WMC petition, particularly operation in the 2450 MHz band, have already been received from the staff at Industry Canada, an agency of the Canadian Government. Similarly, the Mexican Government has expressed its concern regarding unlicensed spread spectrum operations between stations in the U.S. and stations in Mexico.[17] Thus, commenting parties may also wish to address actions that could be taken to limit operation near the Canadian and Mexican borders to avoid unauthorized crossborder operations and interference to licensed systems in Canada and Mexico.

16. Comments are also requested in two additional areas regarding the technical standards for spread spectrum transmission systems operating without a limit on directional antenna gain. The first of these concerns a reduction in the output power of the transmitter based on the amount that the increase in directional antenna gain exceeds the current limit of 6 dBi. We propose that the output power of a transmitter would need to 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.[18] While this would result in a slight reduction in the effective radiated

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[12] 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.

[13] See 47 CFR Sections 2.1043 and 15.203.

[14] See 47 CFR Section 15.205.

[15] See, for example, Notice of Proposed Rule Making in ET Docket No. 93-62, 8 FCC Rcd. 2849 (1993).

[16] See 42 USC Section 4321 et seq.

[17] Unlicensed operation in the Part 15 spread spectrum bands is not permitted in Mexico.

[18] See the proposed new Section 15.247(b)(4) in Appendix B.

power level of the system, the higher gain employed by the antenna would still be available to amplify the received signal.

17. Comments are also requested on whether the rules should specify limits on the horizontal and vertical beamwidths of antennas used with these point-to-point systems. Certain antenna designs, e.g., a horizontally polarized yagi antenna, concentrate the signal strength in azimuth (horizontal) but not in elevation (vertical). However, a fixed, point-to-point system employing an antenna with a wide elevation beamwidth that is pointed towards an office building with multiple floors could result in severe interference problems to any party in that building who is in line with the system and is operating in the same band. Several antenna designs concentrate the radiated signals in both azimuth and elevation, e.g., circular dish antennas and stacked yagi antennas. We believe that any interference problems resulting from excessive vertical emissions could be resolved if the 3 dB beamwidths, in both the vertical and the horizontal planes, of the high gain directional antennas employed with these fixed, point-to-point systems differ by no more than a factor of two and are proposing such a limit.

Symbol Technologies, Inc. (Symbol)

18. The Petition. In its Petition for Rule Making, Symbol requests a reduction in the number of hopping channels, from 75 to 20, required for frequency hopping spread spectrum systems operating in the 2450 MHz and 5800 MHz bands.[19] Under this plan, the average time of occupancy for the hopping transmitter would be limited to no longer than 0.4 seconds on any one channel in any 8 second interval, as opposed to the current limit of 0.4 seconds on any one channel in any 30 second interval. Further, the output power would be reduced from the current one watt peak output to (number of hops/75) watts.[20] Symbol indicates that the proposed changes would raise the effective signal bandwidth of a frequency hopping system from 1 MHz to about 5 MHz.

19. Symbol states that its proposed changes would align U.S. standards for unlicensed spread spectrum systems more closely with the European standards for such equipment, permitting U.S. manufacturers to produce the same equipment for domestic use and for export to Europe. It adds that this, in turn, would reduce the cost of exported goods and increase U.S. exports to Europe. Symbol further states that its proposed language is compatible with the European Telecommunications Standards Institute standard ETS 300-328 for the 2450 MHz band.[21] Symbol also indicates that frequency hopping equipment manufactured under this proposal would be capable of substantially higher data speeds than can be achieved under the present frequency hopping rules. It states that such systems could be used to satisfy customer demands for high speed, low cost wireless computer local area networks (LANs), making it possible for wireless LANs to compete with wired LANs while offering the wireless advantage of portability and flexibility.[22] Symbol also argues, in its petition, that these amendments would not increase the

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19 See RM-8608. Symbol's original petition requested a reduction to 15 hopping channels. Symbol subsequently amended its petition to request a minimum of 20 hopping channels. Additional amendments were also submitted by Symbol regarding the output power of the transmitter and the maximum dwell time the transmitter could remain on a channel. These amendments are presented in the text as if they were part of the original petition. Symbol states that one reason for requesting a reduction in the number of hopping channels was our proposal to allocate the 2402-2417 MHz portion of the band to licensed radio services. However, the Commission decided not to make this allocation and preserved this band for Part 15 operation. See First Report and Order in ET Docket No. 94-32, 10 FCC Rcd. 4769 (1995).

20 This formula represents a linear decrease in output power corresponding to the reduction, below 75, in the number of hopping channels.

21 Symbol also notes that the Japanese standard, RCR STD-33, requires only 10 hopping channels and applies over the much narrower band of 2471-2497 MHz. Symbol does not seek compatibility with the Japanese standard.

22 The current 1 MHz bandwidth limit on individual frequency hopping channels restricts data rates to about 1 Mbps if simple modulation techniques employing 1 bit/sec/Hz efficiency are employed. However, typical wired LANs operate at 10 times that speed. It is possible to push the spectrum efficiency of frequency hopping systems

threat of interference to other users in this spectrum.[23] Further, Symbol adds that the proposed changes to the rules would correct a competitive disparity between direct sequence systems and frequency hopping systems.[24] Finally, Symbol adds that its proposal would not significantly detract from the major advantages of spread spectrum long recognized by the Commission: its ability to enhance spectrum efficiency by sharing spectrum with other services in ways that minimize cross-interference.

20. Comments. Apple Computer, Inc. (Apple), Norand Corporation (Norand), and SpectraLink Corporation (SpectraLink) filed comments supporting Symbol's petition.[25] Norand states that these proposals would foster the joint development of products for both the U.S. and the European markets. Norand also concurs with Symbol's assessment that the proposed changes would not increase the potential for interference to other radio operations, and that frequency hopping systems operating under these relaxed standards would create no greater interference potential than currently caused by direct sequence systems. Apple expresses support for Symbol's proposal, stating that these changes would permit wireless LANs to operate at higher data rates while protecting other users of the band from increased interference and would harmonize our rules with European standards. Apple, however, also adds that Symbol's proposal does not appear to address the risk that narrow band systems employing a few hopping channels could dominate a frequency range and cause that range to appear occupied and unavailable to devices employing wideband channels.[26] Apple is also concerned that the adoption of this proposal could adversely affect the efforts of the Institute of Electrical and Electronic Engineers (IEEE) Standards Working Group P802.11 to develop industry-wide standards for wireless LANs. Apple submits that other Commission actions, including the allocation of spectrum at 2390-2400 MHz and the development of the millimeter wave bands above 40 GHz, may also provide new opportunities for high bandwidth wireless transmissions.[27] SpectraLink concurs with Symbol that a reduction in the minimum number of frequency hopping channels, coupled with a corresponding increase in the permissible channel bandwidth, would allow a higher data throughput, but also urges us to stipulate that the maximum transmitter dwell time per hop on any channel may not exceed 0.4 seconds.

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above 1 bit/sec/Hz, but Symbol states that doing so requires equipment that is too costly and sophisticated for ordinary office equipment. It therefore argues that the 1 MHz bandwidth limit may hinder the widespread deployment of wireless LANs.

23 Symbol recognizes in its reply comments that reducing the number of hopping channels could increase the potential for interference to narrowband systems. Because of this increased interference potential, Symbol agrees that the output power of the transmitter should be reduced as described in the above text.

24 According to Symbol, direct sequence spread spectrum systems, which are permitted to occupy the entire 2450 and 5800 MHz bands, can use a signal bandwidth up to 1/10th as wide as the total bandwidth and still comply with the requirements to achieve a processing gain at the receiver of at least 10 dB.

25 Several commenting parties suggested modifications to Symbol's original petition. These suggestions included increasing the number of hopping channels from 15 to 20, changing the average occupancy time for the hopping channel, and reducing output power to compensate for the reduced number of hopping channels. Since Symbol has modified its filing to include these modifications, these issues, as raised in the comments, are not detailed in our discussion.

26 Apple also agreed with Aironet Wireless Communications, Inc. that this effort to accommodate higher-speed wireless LANs should not be implemented at the expense of other users sharing these bands.

27 See First Report and Order and Second Notice of Proposed Rule Making in ET Docket No. 94-32, 10 FCC Rcd. 4769 (1995). See, also, Notice of Proposed Rule Making in ET Docket No. 94-124, 9 FCC Rcd. 7078 (1994). A First Report and Order and Second Notice of Proposed Rule Making in ET Docket No. 94-124 was adopted and released on December 15, 1995, FCC 95-499, but has not yet been published in the Federal Register or FCC Records.

21. In addition to the concerns raised by Apple, Aironet Wireless Communications, Inc. (Aironet) and AT&T oppose Symbol's request. Aironet contends that the proposed changes would lead to potentially serious interference to other spread spectrum users as well as to primary (licensed) users of these bands. It also states that the use of wider bandwidth transmissions would significantly reduce the processing gain and interference rejection capabilities of frequency hopping systems. Aironet agrees that there will be substantial demand for wireless LANs, but argues that these systems should use direct sequence and other technologies which, it contends, are more than sufficient to meet the technical requirements for wireless LANs. In regard to Symbol's statement that its proposal is similar to European standards, Aironet states that the new European standards came into effect after considerable controversy in 1994, and very few, if any, of these frequency hopping systems have been developed in Europe to date because of the continuing controversy within the industry. AT&T also expresses concern that these rule changes would increase the potential for interference to other devices in the bands. It states that frequency hopping systems using a wider bandwidth would have a greater chance of transmitting on a frequency used by a nearby system and, thus, interfering with that other system. AT&T further states that with fewer hopping channels, frequency hopping systems would frequently collide with each other and with direct sequence systems. This interference would increase as spread spectrum systems proliferate.

22. Some of the comments addressed methods that could provide additional versatility for frequency hopping spread spectrum systems. Apple indicates that it may be advantageous to consider possible alternative numbers of hopping channels, as well as changes in output power for increased bandwidth transmissions. Metricom, Inc. (Metricom) states that the Commission should specify the maximum bandwidth of a hopping channel as a function of the number of hopping channels and should specify a channel distribution in order to ensure that there is an even distribution over the entire frequency band employed. This would prevent the band from becoming "channelized" and would prevent the "bunching" of frequency hopping channels in any particular segment of the spectrum.

23. Discussion. We have serious concerns that implementing Symbol's requested changes could result in severe increases in the potential for harmful interference, both to the authorized radio services[28] and to other Part 15 devices operating in these bands. Symbol's request to decrease the number of hopping channels would result in an increase in the average time during which the channels are occupied by a spread spectrum transmission. In addition, Symbol's request to increase the bandwidth of the hopping channels would broaden the spectrum over which interference from the frequency hopping systems could be received. Thus, we believe that implementing these changes would be detrimental to other narrowband and wideband systems operating in these bands. While this increased interference potential could be partially offset by a reduction in the output power of the frequency hopping transmitters, we are not convinced that a linear power reduction alone is sufficient to offset this interference potential.[29] We also note that any benefit from the reduction in output power could be negated if we adopt the proposal from WMC, described above, to eliminate the current restriction on antenna gain in the 5800 MHz band. In addition, the resulting increase in hopping channel bandwidth would open frequency hopping systems to several new consumer applications, such as analog video transmissions, in addition to the wireless local area network applications described in the petition. Normally, the Commission seeks to encourage new uses of the spectrum. However, in this case we feel that the large increase in the proliferation of these transmitters from additional consumer applications, combined with a smaller number of hopping channels, an increased bandwidth, and increase in average channel occupancy time, and, in some cases, a higher effective radiated power, would result in a significant increase in the probability that harmful interference will occur to other radio operations in these bands.

24. We also observe that there appears to be sufficient spectrum, either currently available or under proposal, to support high data speeds for wireless local area network systems. For example, we have opened 5 GHz

28 The authorized radio services in the 2450 MHz and 5800 MHz bands are described in footnote 13.

29 As indicated by Metricom, Inc. in its discussion of a similar petition from SpectraLink dealing with frequency hopping systems in the 915 MHz band, discussed below, there would be an exponential, not linear, increase in interference due to the statistical nature of the systems' response to collisions.

of spectrum in the 59-64 GHz band, and have proposed to open additional bands above 40 GHz, for consumer applications.[30] In addition, licensed wideband digital transmission systems may be operated under the Personal Communications Services[31], the Private Land Mobile Radio Services[32], and the Private Operational Fixed Microwave Service.[33] Unlicensed wideband digital signals may also be transmitted in the 2450 MHz and 5800 MHz bands using either direct sequence spread spectrum modulation or, at a lower power level, conventional modulation techniques[34] and in the bands 1910-1920 MHz and 2390-2400 MHz.[35] In addition, it is possible under the existing rules to construct frequency hopping systems in the 2450 MHz and 5800 MHz bands that can operate at high data rates through the use of more efficient modulation techniques, such as quadrature amplitude modulation.[36] We are also considering the possibility of providing additional spectrum for unlicensed operations under a Petition for Rule Making from Apple to open the frequency bands at 5150-5300 MHz and 5725-5875 MHz as well as a Petition for Rule Making from the Wireless Information Networks Forum (WINForum) to open spectrum at 5100-5350 MHz.[37]

25. Finally, as indicated in the comments, the IEEE Standards Working Group P802.11 is currently developing industry standards for wireless LANs, including operation in the 2450 MHz band. We are reluctant to propose any changes to the existing spread spectrum standards regarding the transmission of wideband digital systems prior to the release of that Committee's recommendations. While we agree with Symbol that harmonization with the European standards would be advantageous, harmonization is not sufficient, by itself, to overcome all of the potential problems associated with reducing the minimum number of hopping channels. Accordingly, in light of the above considerations we are denying the Petition for Rule Making from Symbol to reduce the minimum number of hopping channels for frequency hopping spread spectrum systems operating in the 2450 MHz or 5800 MHz bands.

SpectraLink Corporation (SpectraLink)

26. The Petition. In its Petition for Rule Making, SpectraLink requests a reduction, from 50 channels to 25 non-contiguous channels, in the number of hopping channels required for frequency hopping spread spectrum systems operating in the 915 MHz band.[38] SpectraLink also requests that frequency hopping systems that use fewer

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30 See Notice of Proposed Rule Making and First Report and Order and Second Notice of Proposed Rule Making in ET Docket No. 94-124, supra.

31 Spectrum is available in several bands between 1850-1910 MHz and 1930-1990 MHz. See 47 CFR Part 24.

32 Spectrum for wideband data is available in the band 2450-2483.5 MHz. See 47 CFR Part 90.

33 Of particular note is subscription operation available in the 18.82-18.87 GHz and 19.16-19.21 GHz bands. See 47 CFR Section 94.88.

34 See 47 CFR Section 15.249.

35 See 47 CFR Sections 15.301 et seq.

36 See, for example, "Hardware Technologies for Adaptive High Bit-Rate Wireless Transceivers," Integrated Circuits and Systems Laboratory, Electrical Engineering Department, University of California, Semi-Annual Technical Report, April 1995, at pg. 11.

37 See RM-8653 and RM-8648, respectively.

38 See RM-8609. The use of non-contiguous frequency hopping channels is already required under the rules. This requirement is contained in the 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 Section 2.1. While we

than 50 hopping channels be limited to a maximum transmitter peak output power of 500 mW. It states that a system operating with 25 hopping channels and a corresponding 3 dB reduction in output power would have the same spectral power density as a system using 50 hopping channels.

27. Adoption of the SpectraLink proposal would allow a reduction, from 25 MHz to 12.5 MHz, in the minimum spectral occupancy of frequency hopping spread spectrum systems operating at the maximum channel bandwidth.[39] SpectraLink indicates that this is necessary because of the recent rule making actions by the Commission allocating the 915 MHz band to the Location Monitoring Service (LMS) under Part 90 of our rules.[40] By decreasing the number of frequency hops, Part 15 spread spectrum systems could avoid operating in the frequency bands used by wideband multilateration LMS systems, preventing mutual interference problems.[41] SpectraLink indicates that this change to reduce the spectral occupancy of spread spectrum systems would maximize the number of Part 15 devices and LMS users that can coexist in the band, would accommodate the future deployment of frequency hopping systems in the band, and would maximize spectral efficiency.

28. Comments. All of the commenting parties generally support SpectraLink's petition. Most parties cite SpectraLink's proposals as an effective means of avoiding the bands used by wideband multilateration LMS systems and state that such an approach would avoid potential interference problems both to and from Part 15 spread spectrum systems. Apple notes that wideband systems utilize virtually the entire 915 MHz band and must hop to, and transmit in, portions of the band that have been allocated to multilateration LMS systems. It adds that SpectraLink's proposal to reduce the number of hopping channels, with an attendant power reduction to retain the same spectral power density, has substantial merit and few, if any, downside results. Apple also points out that since the rule change provides only further latitude, not further restrictions, it will not force Part 15 manufacturers who are content with the current rules to redesign their products.

29. Itron, Inc. requests that the Commission provide a graded power curve based on the number of hopping channels actually used by the spread spectrum transmitter. It adds that the power reductions should be correlated linearly to the number of frequencies on which a device hops. Metricom, however, states that the proposed 500 mW output power limit doesn't fully address the potential for crowding if many transmitters begin to concentrate in the remaining portion of the 915 MHz band. It submits that the potential for interference is exponential, not linear, due to the statistical nature of systems' response to interference (collisions). Metricom also

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are also proposing to amend the definition of frequency hopping systems and pseudorandom sequence, as discussed below, the revised definitions would still require the use of non-contiguous channels. Accordingly, we see no reason to add an additional provision in the regulations stating that frequency hopping is to be performed on non-contiguous channels.

[39] A total of 26 MHz of spectrum is available for spread spectrum systems operating in the 915 MHz band. SpectraLink did not request an increase in the bandwidth of the hopping channels, which is limited to a maximum of 500 kHz.

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

[41] 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 Section 90.357(a). We note that wideband multilateration LMS operations could have an impact on frequency hopping spread spectrum systems designed to use a hopping channel bandwidth of 250 kHz or greater. SpectraLink's request is designed to permit these systems to continue to operate at the current maximum hopping channel bandwidth of 500 kHz.

points out that SpectraLink indicates that its products will operate indoors. According to the new rules regarding sharing between Part 15 devices and the LMS, LMS systems are not protected from interference from Part 15 devices that operate indoors.[42] Thus, Metricom contends that SpectraLink's claim of needing to reduce the number of hopping channels to avoid interference between Part 15 and LMS devices is not sufficient to justify changing the rules.

30. Discussion. As SpectraLink observes, there could be mutual interference problems between wideband, multilateration LMS systems and Part 15 frequency hopping spread spectrum systems, and it would be beneficial if these two operations could avoid sharing the same spectrum. The modification sought by SpectraLink would appear to promote frequency sharing within this band. For these reasons, we believe that the SpectraLink petition, unlike the petition from Symbol, should be adopted. Therefore, we are proposing to amend the rules to permit frequency hopping spread spectrum systems in the 915 MHz band to use only 25 hopping channels, provided that those systems employ hopping channel bandwidths of at least 250 kHz and the transmitters operate at a reduced power level. Hopping systems using channel bandwidths less than 250 kHz already can avoid operating in the bands used by broadband multilateration LMS systems and require no decrease in the minimum number of hopping channels. For frequency hopping systems employing channel bandwidths of 250 kHz or greater, we propose to reduce the minimum number of hopping channels to 25.[43] Consistent with this plan, we are also proposing to modify the maximum average time of occupancy on any hopping frequency to 0.4 seconds in any 10 second period to correspond to the reduction in the number of hopping channels.[44]

31. While SpectraLink's petition raises some of the same interference concerns as the Symbol petition, we see several important differences. We note that, unlike Symbol's request, there would be no increase in the bandwidth of the hopping channel. In addition, the reduction in the number of hopping channels and the corresponding increase in the average channel occupancy time would not be as great as under Symbol's proposal. Further, unlike operation in the 2450 MHz and 5800 MHz bands, we note that multilateration LMS services are expected to grow at a rapid rate, causing frequency congestion problems for Part 15, LMS and other users of the 915 MHz band.

32. We also request 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. 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.[45] 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. 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.

33. In order to reduce the potential for interference due to the smaller number of hopping channels, we propose to require that frequency hopping spread spectrum systems in the 915 MHz band that use fewer than 50

[42] See Report and Order in PR Docket No. 93-61, supra, at para. 32-39, and 47 CFR Section 90.361.

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

[44] 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.

[45] The use of this formula would result in systems employing a hopping channel bandwidth of 250 kHz having to employ at least 50 hopping channels, whereas our proposal above would permit such systems to operate with only 25 hopping channels.

hopping channels operate with a maximum peak transmitter output power of 500 mW. However, as suggested by Metricom, while the potential for harmful interference can be offset by a reduction in operating power, a linear reduction may not be sufficient to provide this offset.[46] We recognize that the chance of collisions with other transmissions, and resulting interference, will 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 are requested as to whether or not a greater reduction in output power should be applied. Comments are 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 less than 50 hopping channels. We also request comments regarding Itron's suggestion to specify a linear power reduction based on the actual number of hopping channels employed. This would result in a maximum peak transmitter output power of no greater than (number of hopping channels/50) watts or 1 watt, whichever is the lesser power.

34. Commenting parties should note that a number of petitions for reconsideration have been received in response to the recent Report and Order implementing the LMS system. Any changes to the LMS rules in response to those petitions may result in modifications to changes for the spread spectrum regulations under Part 15 proposed for the 915 MHz band.

ADDITIONAL PROPOSALS

35. There are several additional regulations concerning Part 15 spread spectrum transmission systems that need to be clarified, codified or amended. These are discussed below.

36. Spectral power density. When the rules for direct sequence systems were modified in 1990, a specification was added for maximum spectral power density. However, the current rules incorrectly state this as an average limit. As stated in the 1990 Report and Order, the reason for the standard on spectral power density was to ensure that the transmitted energy is evenly spread over the minimum channel bandwidth of 500 kHz in order to limit interference to other systems in this band.[47] At the maximum output power level of 1 watt, this equates to a limit of 8 dBm in any 3 kHz band. However, the output limit of a spread spectrum transmitter is based on a peak limit, not an average limit. Accordingly, we propose to change the reference in the rules from an average limit to a peak limit. Additional clarification is shown in the measurement procedure described in Appendix C.[48] We note that all of the direct sequence transmitters authorized by the Commission meet this standard, so there should be no impact to existing equipment from this correction.

[46] 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.

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

[48] The measurement procedures shown in Appendix C were released by the Commission on July 12, 1995, as a Public Notice.

37. Definition of direct sequence. The definition of direct sequence spread spectrum systems contained in the rules has become outdated.[49] For example, the incoming information is always digitized but is not necessarily modulo 2 added to the higher speed code (spreading) sequence. We propose to amend the existing definition to simplify it and to make it more compatible with existing product designs. The proposed new definition is: "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."

38. Definition of pseudorandom sequence and frequency hopping systems. The current definition of a pseudorandom sequence is used to establish standards for frequency hopping systems.[50] 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. We propose 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. The proposed new definition of a frequency hopping system is: "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."

39. Short duration transmissions. The Commission has received a number of applications for frequency hopping systems that transmit only for short periods of time. 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 the 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. Systems requiring short duration transmission

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[49] 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 Section 2.1.

[50] 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 Section 2.1.

bursts are specifically accommodated under different regulations, although at lower power levels.[51] In addition, 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. At the same time, the interference potential is decreased due to the short duration of the transmission. We propose to leave these criteria intact, requiring that products being authorized as frequency hopping systems be capable of acting as frequency hopping systems. However, we request comments on these issues and will 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. Measurement of processing gain. Under our 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 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.[52] However, we note 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. In these cases, we permit an indirect measurement of processing gain based on the receiver jamming margin.[53] Some manufacturers have indicated that processing gain could be based on the ratio of the chipping (spreading) rate to data rate, which shows the maximum possible gain with a perfect receiver. 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, we believe it is necessary to require a demonstration of the improvement in received signal-to-noise ratio produced by the spreading/despreading process. Thus, we are proposing to incorporate the measurement procedure shown in Appendix C into the regulations to provide an alternative method of measuring processing gain. Interested parties are invited to comment on this proposal and to submit suggestions for alternative methods of measuring the processing gain of the complete spread spectrum system.

42. Limits on unwanted emissions. 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 attenuation limits for specific spurious signals and whether these standards 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 these transmitters.[54] We propose 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. We further propose 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, we propose to reference in the spread spectrum rules the requirements for the attenuation of radiated

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[51] See, for example, 47 CFR Sections 15.231(e) and 15.249.

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

[53] 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.

[54] See 47 CFR Section 15.205.

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.

43. Frequency hopping coordination. Several manufacturers have 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.[55] The resulting greater average occupancy of spectrum from a coordinated system would increase the interference potential to other services, undermining the Commission's intent to establish spread spectrum standards to facilitate spectrum sharing.[56] We propose to permit the operation of frequency hopping spread spectrum systems that individually and independently choose and adapt their hopsets to react to the environment in which the system is operating, moving themselves out of the way should another user come on the air in the same band. While this proposal would permit coordination between intelligent frequency hopping transmitters, this method of coordinating transmission systems would not result in an increase in interference potential to other users of the spectrum. Accordingly, we believe that this coordination method should be permitted under the rules.

44. External radio frequency power amplifiers. We have noticed that several companies are now marketing external radio frequency power amplifiers for use with Part 15 spread spectrum transmission systems to increase transmission range. Manufacturers are also marketing replacement antenna systems with higher directional gains to increase transmission range. The marketing and use of these amplifiers or antennas violates Federal law and our regulations.[57] The rules specifically limit the output power of the transmitter, the equivalent isotropically radiated power from the combination of the transmitter and the antenna, and the levels of the radiated emissions in certain restricted frequency bands.[58] The addition of an external radio frequency power amplifier or of an antenna other than the one with which the spread spectrum transmission system was originally certified can cause the system to exceed these limits and the use of this system to violate the rules. However, the Part 15 rules do not specifically discuss external amplifiers or replacement antennas by name. Thus, some equipment manufacturers may not be aware of our requirements. Accordingly, we propose to clarify our regulations by adding a new section that prohibits the manufacture, importation, marketing and use of external radio frequency power amplifiers intended for use with Part 15 transmitters that are not certified as part of a Part 15 system.[59] Similarly, we propose to amend the

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[55] Frequency hopping spread spectrum systems must hop to frequencies that are selected from a pseudorandomly ordered list of frequencies. See 47 CFR Section 2.1 and Section 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."

[56] An example of the problem that could occur from coordinated frequency hopping transmitters is as follows: if 50 frequency hopping transmitters located in the same general vicinity and operating with 500 kHz channels in the 915 MHz band are allowed to coordinate hopping channels, the entire 915 MHz band would be occupied on a continuous basis, allowing no room for other users.

[57] See 47 USC Sections 301 and 302. See, also, 47 CFR Section 15.1.

[58] See 47 CFR Sections 15.205 and 15.247. The regulations also require that the transmitter be designed to prevent the use of any antenna other than the one with which it was originally certified. See 47 CFR Section 15.203.

[59] This proposal would not prohibit the marketing of external radio frequency power amplifiers for use in the Amateur Radio Service.

regulations to state that the use of an antenna, other than the type with which the product was originally certified, is in violation of the rules. Since the prohibition against the use of external amplifiers or after-market antennas is equally applicable to all Part 15 transmission systems, we further propose that this amendment apply to all Part 15 transmission systems.

45. Transition provisions. With the exception of limits on directional antenna gain, the amendments being proposed in this proceeding add and/or clarify permissible methods of operation and should not impact any existing equipment designs. As mentioned above, waivers were issued to WMC, Cylink Corporation and Atlantic Communications Sciences to manufacture fixed, point-to-point spread spectrum systems in the 2450 MHz and 5800 MHz bands without a limit on directional antenna gain. These manufacturers would be impacted by a decision rejecting the use of high gain directional antennas with systems operating the in 2450 MHz band. However, under the terms of the waivers, this equipment can be manufactured until June 23, 1996, or until final action on the Petition for Rule Making from WMC, whichever occurs earlier. Thus, these manufacturers are aware of the possibility that their waivers may not continue subsequent to finalization of this rule making proceeding. At the same time, we wish to make the benefits associated with the changes being proposed in this proceeding available to all manufacturers and operators of spread spectrum transmission systems as soon as possible. Accordingly, we propose that changes to the regulations adopted in response to this proceeding become effective upon the date of publication of the final rules in the Federal Register.

PROCEDURAL MATTERS

46. This is a non-restricted notice and comment rule making proceeding. Ex parte presentations are permitted, except during the Sunshine Agenda period, provided they are disclosed as provided in the Commission's rules. See generally 47 CFR Sections 1.1202, 1.1203, and 1.1206(a).

47. Initial Regulatory Flexibility Analysis. As required by Section 603 of the Regulatory Flexibility Act, the Commission has prepared an Initial Regulatory Flexibility Analysis (IRFA) of the expected impact on small entities of the proposals suggested in this document. The IRFA is set forth in Appendix A. Written public comments are requested on the IRFA. These comments must be filed in accordance with the same filing deadlines as comments on the rest of the Notice, but they must have a separate and distinct heading designating them as responses to the Initial Regulatory Flexibility Analysis. The Secretary shall send a copy of this Notice of Proposed Rule Making, including the Initial Regulatory Flexibility Analysis, to the Chief Counsel for Advocacy of the Small Business Administration in accordance with paragraph 603(a) of the Regulatory Flexibility Act. Pub. L. No. 96-354, 94 Stat. 1164, 5 U.S.C. Section 601 et seq (1981).

48. Comment Dates. Pursuant to applicable procedures set forth in Sections 1.415 and 1.419 of the Commission's Rules, 47 C.F.R. Sections 1.415 and 1.419, interested parties may file comment on or before [insert date 75 days from date of publication in the Federal Register] and reply comments on or before [insert date 105 days from date of publication in the Federal Register]. To file formally in this proceeding, you must file an original and five copies of all comments, reply comments, and supporting comments. If you want each Commissioner to receive a personal copy of your comments, you must file an original plus nine copies. You should send comments and reply comments to Office of the Secretary, Federal Communications Commission, Washington, D.C. 20554. Comments and reply comments will be available for public inspection during regular business hours in the FCC Reference Center of the Federal Communications Commission, Room 239, 1919 M Street, N.W., Washington, D.C. 20554.

49. For the reasons described above, IT IS ORDERED that the Petition for Rule Making from Symbol Technologies, Inc., IS DENIED. The proposed action, including the denial of Symbol's Petition for Rule Making, is authorized under Sections 4(i), 301, 302, 303(e), 303(f), 303(r), 304 and 307 of the Communications Act of 1934, as amended, 47 U.S.C. Sections 154(i), 301, 302, 303(e), 303(f), 303(r), 304 and 307.

50. For further information regarding this Notice of Proposed Rule Making, contact John Reed, Office of Engineering and Technology, (202) 418-2455.

FEDERAL COMMUNICATIONS COMMISSION

William F. Caton
Acting Secretary

APPENDIX A

INITIAL REGULATORY FLEXIBILITY ANALYSIS

Reason for Action

This rule making proceeding is initiated to obtain comment regarding proposed changes to the regulations for non-licensed spread spectrum transmitters.

Objectives

The Commission seeks to determine if the standards should be amended as sought in Petitions for Rule Making filed by WMC, Symbol and SpectraLink. Additional amendments are also proposed to clarify the existing regulations and to codify existing policies into the rules.

Legal Basis

The proposed action is authorized under Sections 4(i), 301, 302, 303(e), 303(f), 303(r), 304 and 307 of the Communications Act of 1934, as amended, 47 U.S.C. Sections 154(i), 301, 302, 303(e), 303(f), 303(r), 304 and 307.

Reporting, Recordkeeping and Other Compliance Requirements

Part 15 spread spectrum transmitters are already required to be authorized under the Commission's certification procedure as a prerequisite to marketing and importation. The changes proposed in this proceeding would not change any of the current reporting or recordkeeping requirements. Further, the proposed regulations add permissible methods of operation and would not require the modification of any existing products.

Federal Rules Which Overlap, Duplicate or Conflict With These Rules

None.

Description, Potential Impact and Number of Small Entities Involved

The actions proposed in this proceeding add permissible methods of operation and will not require the modification of any existing products. Accordingly, there should be no mandatory impact on any small entities.

Any Significant Alternatives Minimizing the Impact on Small Entities Consistent with Stated Objectives

None.

APPENDIX B

PROPOSED CHANGES TO THE REGULATIONS

I. Title 47 of the Code of Federal Regulations, Part 2, is proposed to be amended as follows:

1. The authority citation for Part 2 continues to read as follows:

AUTHORITY: Sec. 4, 302, 303, and 307 of the Communications Act of 1934, as amended, 47 U.S.C. Sections 154, 302, 303 and 307, unless otherwise noted.

2. Section 2.1, paragraph (c), is amended by deleting the definition for "pseudorandom sequence" and by revising the following definitions to read as follows:

Section 2.1 Terms and definitions.

* * * * *

(c) * * *

* * * * *

Direct Sequence Systems. A spread spectrum system in which the carrier has been modulated by a high speed spreading 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.

* * * * *

Frequency Hopping Systems. 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 of 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.

* * * * *

II. Title 47 of the Code of Federal Regulations, Part 15, is proposed to be amended as follows:

1. The authority citation for Part 15 continues to read as follows:

AUTHORITY: Secs. 4, 302, 303, 304, 307 and 624A of the Communications Act of 1934, as amended, 47 U.S.C. 154, 302, 303, 304, 307 and 544A.

2. Section 15.3 is amended by adding a new paragraph (bb), to read as follows:

Section 15.3 Definitions.

* * * * *

(bb) External radio frequency power amplifier. A device which is not an integral part of an intentional radiator as manufactured and which, when used in conjunction with an intentional radiator as a signal source, is capable of amplifying that signal.

3. Part 15 is amended by adding a new Section 15.204, to read as follows:

Section 15.204 External radio frequency power amplifiers and antenna modifications.

(a) Except as otherwise described in paragraph (b) of this section, no person shall use, manufacture, sell or lease, offer for sale or lease (including advertising for sale or lease), or import, ship, or distribute for the purpose of selling or leasing, any external radio frequency power amplifier or amplifier kit intended for use with a Part 15 intentional radiator.

(b) A transmission system consisting of an intentional radiator, an external amplifier, and an antenna, may be authorized, marketed and used under this part. However, when a transmission system is authorized as a system, it must always be marketed as a complete system and must always be used in the configuration in which it was authorized.

(c) External radio frequency power amplifiers shall not be marketed as separate products. Such amplifiers shall only be marketed in the system configuration with which the amplifier was originally authorized.

(d) Only the antenna with which an intentional radiator is originally authorized may be used with the intentional radiator.

4. Section 15.247 is amended by revising paragraphs (a)(1)(i), (b), (c), (d), and (e), to read as follows:

Section 15.247 Operation within the bands 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz.

(a) * * *

(1) * * *

(i) For frequency hopping systems operating in the 902-928 MHz band: if the 20 dB bandwidth of the hopping channel is less than 250 kHz, 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 20 dB bandwidth of the hopping channel is 250 kHz 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 20 dB bandwidth of the hopping channel is 500 kHz.

(ii) * * *

(2) * * *

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

(1) For frequency hopping systems operating in the 2400-2483.5 MHz or 5725-5850 MHz band and for all direct sequence systems: 1 watt.

(2) For frequency hopping systems operating in the 902-928 MHz band: 1 watt for systems employing at least 50 hopping channels; and, 0.5 watts for systems employing less than 50 hopping channels, as permitted under paragraph (a)(1)(i) of this section.

(3) Except as shown below, if transmitting antennas of directional gain greater than 6 dBi are used the peak output power from the intentional radiator shall be reduced below the above stated values by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

(4) Systems operating in the 5725-5850 MHz band that are used exclusively for fixed, point-to-point operations may employ transmitting antennas with directional gain greater than 6 dBi provided the peak output power of the intentional radiator is reduced by 1 dB for every 3 dB that the directional gain of the antenna exceeds 6 dBi.

(i) Fixed, point-to-point operation excludes the use of point-to-multipoint systems, omnidirectional applications, and multiple co-located intentional radiators transmitting the same information.

(ii) The operator of the spread spectrum intentional radiator 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 of this responsibility.

(iii) Systems operating under the provisions of (b)(4) of this section shall not be market to, or used by, the general public. The marketing and use of these systems shall be restricted to commercial and industrial applications. The responsible party, as defined in Section 2.909 of this Chapter, is responsible for ensuring compliance with this marketing requirement.

(iv) The 3 dB beamwidths, in both the horizontal and vertical planes, of antennas employed under the provisions of (b)(4) of this section shall not differ by more than a factor of two.

(v) Systems operating under the provisions of (b)(4) of this section shall employ positive means to ensure that the public is not exposed to excessive radio frequency energy levels. The method(s) used to prevent such exposure shall be described in the application for the grant of equipment authorization submitted to the Commission.

(c) In any 100 kHz bandwidth outside the frequency band in which the spread spectrum intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement. 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)).

(d) For direct sequence systems, the peak power spectral density conducted from the intentional radiator to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.

(e) The processing gain of a direct sequence system shall be at least 10 dB. The processing gain represents the improvement to the received signal-to-noise ratio, after filtering to the information bandwidth, from the spreading/despreading function. The processing gain may be determined using one of the following methods:

(1) As measured at the demodulate output of the receiver: the ratio in dB of the signal-to-noise ratio with the system spreading code turned off to the signal-to-noise ratio with the system spreading code turned on.

(2) As measured using the CW jamming margin method: a signal generator is stepped in 50 kHz increments across the passband of the system, recording at each point the generator level required to produce the recommended Bit Error Rate (BER). This level is the jammer level. The output power of the intentional radiator is measured at the same point. The jammer to signal ratio (J/S) is then calculated, discarding the worst 20% of the J/S data points. The lowest remaining J/S ratio is used to calculate the processing gain, as follows: Gp = (S/N)o + Mj + Lsys, where Gp = processing gain of the system, (S/N)o = signal to noise ratio required for the chosen BER, Mj = J/S ratio, and Lsys = system losses. Note that total losses in a system, including intentional radiator and receiver, should be assumed to be no more than 2 dB.

* * * * *

APPENDIX C

FEDERAL COMMUNICATIONS COMMISSION

Equipment Authorization Division
7435 Oakland Mills Road
Columbia, MD 21046
Telephone: (301) 725-1585
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Guidance on Measurements for Direct Sequence Spread Spectrum Systems

Part 15 of the FCC Rules provides for operation of direct sequence spread spectrum transmitters. Examples of devices that operate under these rules include radio local area networks, cordless telephones, wireless cash registers, and wireless inventory tracking systems.

The Commission frequently receives requests for guidance as to how to perform measurements to demonstrate compliance with the technical standards for such systems. No formal measurement procedure has been established for determining compliance with the technical standards. Such tests are to be performed following the general guidance in Section 15.31 of the FCC Rules and using good engineering practice. The following provides information on the measurement techniques the Commission has accepted in the past for equipment authorization purposes. Alternative techniques may be acceptable upon consultation and approval by the Commission staff. The information is organized according to the pertinent FCC rule sections.

Section 15.31(m): This rule specifies the number of operating frequencies to be examined for tunable equipment.

Section 15.207: Power line conducted emissions. If the unit is AC powered, an AC power line conducted test is also required per this rule.

Section 15.247(a)(2): Bandwidth. Make the measurement with the spectrum analyzer's resolution bandwidth (RBW) = 100 kHz. In order to make an accurate measurement, set the span >> RBW.

Section 15.247(b): Power output. This is an RF conducted test. Use a direct connection between the antenna port of the transmitter and the spectrum analyzer, through suitable attenuation. Set the RBW > 6 dB bandwidth of the emission or use a peak power meter.

Section 15.247(c): Spurious emissions. The following tests are required :

(1) RF antenna conducted test: Set RBW = 100 kHz, Video bandwidth (VBW) > RBW, scan up through 10th harmonic. All harmonics/spurs must be at least 20 dB down from the highest emission level within the authorized band *as measured with a 100 kHz RBW.*

(2) Radiated emission test: Applies to harmonics/spurs that fall in the restricted bands listed in Section 15.205. The maximum permitted average field strength is listed in Section 15.209. A pre-amp (and possibly a high-pass filter) is necessary for this measurement. For measurements above 1 GHz, set RBW = 1 MHz, VBW = 10 Hz, Sweep: Auto. If the emission is pulsed, modify the unit for continuous operation, use the settings shown above, then correct the reading by subtracting the peak-average correction factor, derived from the appropriate duty cycle calculation. See Section 15.35(b) and (c).

Section 15.247(d): Power spectral density. Locate and zoom in on emission peak(s) within the passband. Set RBW = 3 kHz, VBW > RBW, sweep = (SPAN/3 kHz) e.g., for a span of 1.5 MHz, the sweep should be $1.5 \times 10^6 \div 3 \times 10^3$ = 500 seconds. The peak level measured must be no greater than +8 dBm. If external attenuation is used, don't forget to add this value to the reading. Use the following guidelines for modifying the power spectral density measurement procedure when necessary.

- For devices with spectrum line spacing greater than 3 kHz no change is required.
- For devices with spectrum line spacing equal to or less than 3 kHz, the resolution bandwidth must be reduced below 3 kHz until the individual lines in the spectrum are resolved. The measurement data must then be normalized to 3 kHz by summing the power of all the individual spectral lines within a 3 kHz band (in linear power units) to determine compliance.
- If the spectrum line spacing cannot be resolved on the available spectrum analyzer, 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. Add 30 dB for correction to 3 kHz.
- Should all the above fail or any controversy develop regarding accuracy of measurement, the Laboratory will use the HP 89440A Vector Signal Analyzer for final measurement unless a clear showing can be made for a further alternate.

Section 15.247(e): Processing Gain. The Processing Gain may be measured using the CW jamming margin method. Figure 1 shows the test configuration. The test consists of stepping a signal generator in 50 kHz increments across the passband of the system. At each point, the generator level required to produce the recommended Bit Error Rate (BER) is recorded. This level is the jammer level. The output power of the transmitting unit is measured at the same point. The Jammer to Signal (J/S) ratio is then calculated. Discard the worst 20% of the J/S data points. The lowest remaining J/S ratio is used when calculating the Processing Gain.

In a practical system, there are always implementation losses which degrade the performance below that of an optimal theoretical system of the same type. Losses occur due to non-optimal filtering, lack of equalization, LO phase noise, "corner cutting in digital processing", etc. Total losses in a system, including transmitter and receiver, should be assumed to be no more than 2 dB.

The signal to noise ratio for an ideal non-coherent receiver is calculated from:

(1) $$Pe = \tfrac{1}{2}e^{(-\frac{1}{2}(S/N)o)}$$

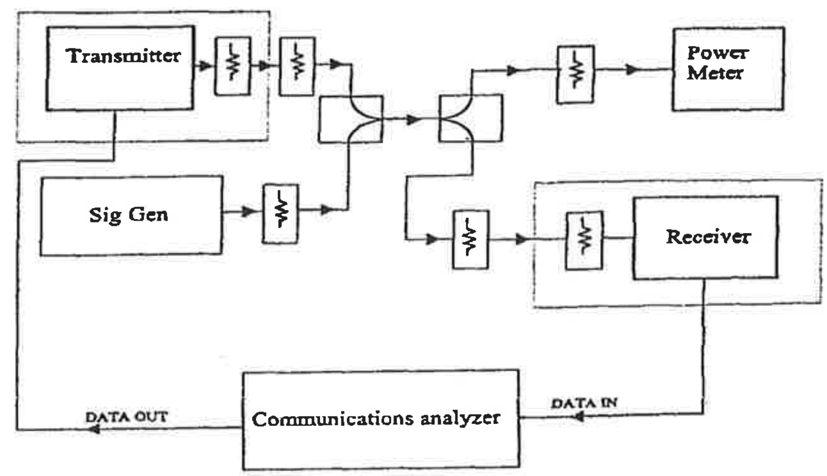
where : *Pe* = probability of error (BER)
(S/N)o = the required signal to noise ratio at the receiver output for a given received signal quality

This is an example. You should use the equation (or curve) dictated by your demodulation scheme.

Ref.: Viterbi, A. J. Principles of Coherent Communications, (New York: McGraw-Hill 1966), Pg. 207

Using equation (1) shown above, calculate the signal to noise ratio required for your chosen BER. This value and the measured J/S ratio are used in the following equation to calculate the Processing Gain (Gp) of the system.

$$Gp=(S/N)o+Mj+Lsys$$



Jamming Test Setup
Figure 1

where: *(S/N)o* = Signal to noise ratio
Mj = J/S ratio
Lsys = System losses.

Ref.: Dixon, R., Spread Spectrum Systems (New York: Wiley, 1984), Chapter 1.

ALTERNATIVE TEST PROCEDURES

If antenna conducted tests cannot be performed on this device, radiated tests to show compliance with the various conducted requirements of Section 15.247 are acceptable. As stated previously, a pre-amp must be used in making the following measurements.

1) Calculate the transmitter's peak power using the following equation:

$$E = \frac{\sqrt{30PG}}{d}$$

Where: E is the measured maximum field strength in V/m utilizing the widest available RBW.
G is the numeric gain of the transmitting antenna over an isotropic radiator.
d is the distance in meters from which the field strength was measured.
P is the power in watts for which you are solving:

$$P = \frac{(Ed)^2}{30G}$$

2) Measure the power spectral density as follows:

A. Tune the analyzer to the highest point of the maximized fundamental emission. Reset the analyzer to a RBW = 3 kHz, VBW > RBW, span = 300 kHz, sweep = 100 sec.

B. From the peak level obtained in (A), derive the field strength, E, by applying the appropriate antenna factor, cable loss, pre-amp gain, etc. Using the equation listed in (1), calculate a power level for comparison to the +8 dBm limit.