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

GEN. Docket No. 89-354

In the Matter of

Amendment of Parts 2 and 15 of the Rules with regard to the operation of spread spectrum systems

REPORT AND ORDER
(Proceeding Terminated)

Adopted: June 14, 1990; Released: July 9, 1990

By the Commission:

INTRODUCTION

1. By this action, the Commission is amending Parts 2 and 15 of its rules to facilitate greater flexibility in the design and use of low power, non-licensed spread spectrum systems. These rule changes provide clarification of the minimum operating characteristics for direct sequence and frequency hopping systems to qualify for operation under the Part 15 rules and expand and refine the permissible operating characteristics for frequency hopping systems. The new rules will significantly increase the potential range of permissible designs for Part 15 spread spectrum systems and thereby broaden the opportunities for development and use of this important new technology.

BACKGROUND

2. 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 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. Spread spectrum systems offer two important technological advantages over conventional transmission schemes. First, the 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. Second, the signal processing in spread spectrum systems tends to suppress undesired signals, thereby enabling such systems to tolerate strong interfering signals. This results in significantly higher signal to noise ratios than can be achieved by conventional techniques such as AM that use no bandwidth spreading. The improvement in signal to noise ratio is termed "processing gain."[1]

3. The two most common types of spread spectrum systems are direct sequence and frequency hopping. Direct sequence systems combine the information signal, which is usually digital, with a much faster stream of binary code. The combined information and code signal is then used to modulate a radiofrequency (RF) carrier. The binary code dominates the modulating function and is the direct cause of the wide spreading of the transmitted signal. This code is a fixed-length pseudorandom sequence of bits. The system continuously recycles the same binary code. Frequency hopping systems spread their energy by changing, or "hopping", the center frequency of the transmission many times a second in accordance with a pseudorandomly generated list of channels. The same sequence of channels is used repeatedly, so that the transmitter continuously recycles the same series of channel shifts.

4. A spread spectrum system's performance, in terms of minimizing interference to other signals and improving processing gain, is determined in large part by attributes of the pseudorandom sequence, or "spreading code," used to spread the RF carrier. The degree to which interference to other signals is reduced depends on the length of the spreading code, i.e., the number of bits or channels in the code.[2] The processing gain is determined by the rate at which the spreading code is generated, i.e., the number of bits or channel hops produced per unit of time.

5. On May 9, 1985, in the *First Report and Order* in General Docket No. 81-413, the Commission, *inter alia,* authorized the operation of low power, non-licensed spread spectrum systems under Part 15 of the rules.[3] Because of their low interference potential, spread spectrum systems operating under Part 15 are permitted greater output power (up to 1 Watt) than other Part 15 devices. The Part 15 rules limit spread spectrum operations to direct sequence and frequency hopping systems. These rules provide that direct sequence systems must have a 6 dB bandwidth of at least 500 kHz. Frequency hopping systems are required to use at least 75 hopping frequencies that are separated by at least 25 kHz. The average time on any one frequency cannot exceed 0.4 seconds within a 30-second period.

6. Since the adoption of these rules, the Commission has received many inquiries regarding the application of the rules in the design of direct sequence spread spectrum systems. These inquiries indicated that the rules do not provide adequate guidance regarding the minimum parameters for a direct sequence system to qualify as a spread spectrum system. The inquiries specifically addressed the minimum spreading code length and the minimum processing gain that are acceptable for a direct sequence spread spectrum system to be considered a spread spectrum system under Part 15. The present rules do not define minimum values for these parameters. Several parties also applied for waivers of the hopping channel bandwidth requirement for frequency hopping systems, maintaining that wider hopping channel bandwidths would allow higher speed transmission of data for such applications as wireless local area networks, while reducing the potential for interference to other users of the band.

7. On August 9, 1989, the Commission adopted a *Notice of Proposed Rule Making (NPRM)* proposing rule changes to address industry's concerns and further facilitate the operation of viable Part 15 spectrum systems.[4] The parties submitting comments and reply comments to the *NPRM*

are listed in Appendix A. Several of the comments are from parties that are developing wireless data terminals using spread spectrum techniques. Several utility groups also submitted comments indicating their interest in the development of spread spectrum systems for load management and remote meter reading purposes. The commenting parties generally support the basic thrust of the proposals. They state that these changes will better facilitate the use of spread spectrum technology for such applications as radio local area networks and personal communications networks.

DISCUSSION AND DECISION

8. Part 15 spread spectrum technologies offer important new opportunities for developing new short range communications capabilities. As indicated in the comments and by the waiver requests we have received, the number and nature of possible applications for low power spread spectrum systems are increasing rapidly. We desire to encourage the development and implementation of this exciting new family of technologies, and therefore seek to provide an appropriate regulatory framework in which there is maximum flexibility for the use of spread spectrum systems consistent with the basic precept of the Part 15 rules that non-licensed operations are not to cause harmful interference to established services.[5] To this end we are making a number of changes to our rules pertaining to operation of Part 15 spread spectrum equipment, as discussed below.

9. *Minimum Performance Standards.* To address the qualifications issue for direct sequence systems, the Commission proposed to specify a pseudorandom sequence of 127 bits as the minimum spreading code length. Alternative spreading codes were to be allowed as long as the spreading of the resulting emissions was at least as random as that which would be produced using a code which generated 127 bits before repeating. In addition, comments were requested on alternative ways of generating the spreading in direct sequence systems. Comments were invited as to whether a processing gain standard needed to be specified for these systems or whether the specification of a processing gain would be redundant regulation. Comments were also requested as to whether a processing gain standard was necessary to ensure that the systems (transmitters and receivers) operating under these rules employed true spread spectrum technology, as opposed to transmitters that spread their signals only to take advantage of the 1 Watt power limit and do not require a spread spectrum receiver.

10. Few of the respondents favor the specification of a minimum spreading code length of 127 bits for direct sequence systems. And, although most of the respondents favor some sort of a spectral density standard, no one firmly endorses the spectral density standard that was alternatively proposed in the *NPRM.* This standard would require measuring 1024 frequency points between the 6 dB points of the emission and comparing the ratio of the standard deviation of these 1024 points to the sample mean and then finally comparing this ratio to some standard. Most of the respondents favor a simpler spectral density standard based upon the even spreading of the 1 Watt power either over the entire allowed bandwidth, as suggested by Agilis and Micrilor, or over the 500 kHz minimum bandwidth specified for these systems in the present rules, as suggested by AT&T, Gambatte, PA Consulting Group, and Salient Communications. Telesystems concurs with this latter group and states that forcing the system designer to spread the transmitted energy across the entire band would significantly reduce the technology options available and ultimately would reduce the benefit to the final user. Telesystems believes that the power spectral levels suggested by Agilis and Micrilor are too low.

11. Many respondents recommend a measurement interval of 30 kHz; AT&T suggests a measurement interval of 3 kHz. Salient Communications observes that too wide a measurement bandwidth will 'average out' the gross irregularities in the power spectral densities of inadequately designed systems and will smooth over distortions in power spectral density due to poor transmitter design. A few parties suggest values for the time interval over which the measurement is to be done. Some maintain that a measurement time of 400 milliseconds would be an appropriate choice since it would be consistent with the occupancy time for frequency hopping systems. Others suggest a measurement time of 5 seconds.

12. As indicated by the record, the absence of clear standards for minimum performance characteristics has made it difficult for system designers to determine whether a particular system qualifies as a spread spectrum system under the Part 15 rules. Our goal in establishing these standards is to define the minimum performance characteristics a system must embody to possess the interference limiting and spectrum efficiency qualities of a spread spectrum system while at the same time provide for maximum flexibility in system design. As noted above we are concerned that the transmitted energy is spread uniformly over a sufficiently broad bandwidth to minimize the potential for interference to established services. We agree with the commenting parties that establishing a minimum spreading code of 127 bits would unnecessarily constrain design. Further, we agree with the overwhelming majority of commenting parties that this objective can be achieved by measuring power spectral density. We find that a power spectral density standard based on 1 Watt spread over the minimum permitted bandwidth of 500 kHz is an appropriate solution. This standard will specify that the maximum allowed power spectral density is 8 dBm in any 3 kHz bandwidth. We have chosen the 3 kHz bandwidth because it is convenient for measurement purposes. This is a standard swept-filter bandwidth on a spectrum analyzer. We are also requiring that the measurement time for any given 3 kHz bandwidth be no less than 1 second. This strikes a reasonable balance among the commenting parties' suggestions.[6]

13. The respondents are divided in their opinion as to whether a minimum processing gain needs to be specified for direct sequence systems. Most respondents are in agreement that such a specification would be difficult to define because of the vast technological differences between the currently allowed spread spectrum systems. Those opposed to the establishment of such a standard generally argue that it is not necessary because the spreading of the signal alone would protect other users of the spectrum from harmful interference. The PA Consulting Group asserts that the reduction of interference potential comes from the spreading process rather than the despreading process associated with processing gain. On the other hand, NCR, Omnipoint and Telesystems see the need for the specification of a system processing gain. They state that merely prescribing a minimum bandwidth

specification is not sufficient because that can be achieved by using high data rates with no spreading at all. NCR believes that, as a general matter, in the absence of a minimum processing gain specification, Parts 2 and 15 do not provide a clear definition of "spread spectrum systems" and there is insufficient guidance as to what the Commission's requirements for certification might be. NCR proposes a minimum processing gain of 10 dB, with the requirement applied to both the transmitter and receiver as a system. Omnipoint proposes a 10 dB processing gain measured at the receiver. Telesystems recommends that manufacturers be required to show that their receivers can withstand a 6 dB jamming margin.

14. Very closely allied to the specification of a system processing gain is the specification of receiver standards. Telesystems states that effective despreading to achieve processing gain in a spread spectrum receiver is technically complex and can be expensive to implement. According to Telesystems, the process of spreading in the transmitter is, on the other hand, both simple and inexpensive. Telesystems maintains that, to avoid abuse, a requirement must be imposed on the receiver to ensure the majority of the energy transmitted is, in fact, usefully processed. Telesystems believes that such a requirement could be achieved by specifying a minimum receiver sensitivity or processing gain. Others like Apple and Gambatte state that the Commission's focus should be entirely on the spreading characteristics of the transmitter because interference to other users of the frequencies is caused by the transmitter and not the receiver. NYNEX contends that if manufacturers choose to market receivers that provide none of the interference rejection capabilities of spread spectrum then customers looking for high quality performance, as opposed to low prices, will not buy these products.

15. We agree with NCR and Omnipoint that a processing gain requirement is needed for direct sequence systems to ensure that such systems operated under Part 15 rules are, in fact, spread spectrum in nature. We also agree that, without a processing gain requirement, the concept of spread spectrum operation is not clearly defined and insufficient guidance is provided to industry as to what actually is acceptable to the Commission as a spread spectrum system. Further, in the absence of a processing gain requirement, there is a strong potential for abuse of the Part 15 spread spectrum provisions. Devices could be designed to take advantage of the 1 Watt power provision by generating spread bandwidths where much of the energy is completely unnecessary for communications. These unnecessary signals constitute an inefficient use of the radio spectrum. We are adopting the definition of processing gain recommended by Gambatte, that is, processing gain is the unprocessed signal to noise ratio of the receiver versus the post-processed signal to noise ratio.

16. We reject the arguments that we should apply our definitional requirements only to transmitters and not to receivers. In our experience, we have found that it is necessary to consider the characteristics of both the transmitter and receiver to determine if true spread spectrum techniques are being used. It was our intent in establishing these regulations to provide for and encourage spread spectrum technology. The 1 Watt power provision was intended to be a strong incentive in this regard. We deemed it desirable to foster this technology because of its low propensity to cause interference and its relatively high tolerance of interference from other sources. We do not believe it is in the public interest to allow the intent of these regulations to be undercut by systems that generate broad bandwidths only to take advantage of the 1 Watt permitted power. We reject those comments suggesting that the Commission should only be interested in whether the transmitter signals have potential for causing interference. The interests of spectrum efficiency dictate that we take steps to ensure against the transmission of radio frequency energy that serves no useful purpose for communication, may result in interference and can be avoided. We also see no practical way to measure processing gain based on the transmitter alone.

17. Consistent with the recommendation of NCR and Omnipoint, we are requiring a processing gain of 10 dB for direct sequence systems as measured at the demodulated output of the receiver. Based on our observations of the characteristics of spread spectrum systems submitted for certification, we believe the 10 dB requirement can be met with little difficulty. Large-scale integrated circuit designs may present difficulties for some equipment manufacturers to access a suitable measurement point for signal to noise ratio measurements. In this instance, applicants for equipment authorization may consult with Commission staff on alternate methods. We are amending Section 2.1033 of our rules to require that applications for certification of direct sequence spread spectrum systems under Part 15 shall be accompanied by an exhibit demonstrating how the system achieves the required 10 dB of processing gain. We feel that this approach is superior to Telesystems' suggestion to establish a requirement for a receiver jamming margin, which would require specifying a jamming signal.

18. *Frequency Hopping Systems.* The Commission proposed several rule changes to facilitate greater flexibility in the design and operation of frequency hopping systems. The most significant proposal was to increase the hopping channel bandwidth for such systems from 25 kHz to 500 kHz. To accommodate the increased channel bandwidth in the 902-928 MHz band and still retain the nonoverlapping hopping channel requirement, the required number of hopping frequencies for systems using this band was proposed to be reduced from 75 to 50. Further, the Commission proposed to reduce the maximum occupancy time on any frequency from 400 milliseconds in any 30 second period to 100 milliseconds per 5 second interval for frequency hopping systems operating in the 902-928 Mhz band and to 100 milliseconds per 7.5 second interval for frequency hopping systems operating in the 2400-2483.5 and 5725-5850 Mhz bands. To clarify the intent of the existing rules requiring use of at least 75 hopping frequencies, the Commission proposed that each hopping frequency be selected at least once before the hopping sequence repeated.

19. The commenting parties are unanimous in their support of the Commission's proposal to increase the frequency hopping channel bandwidth from 25 kHz to 500 kHz. Gambatte favors increasing this bandwidth to 1 MHz. The commenting parties state that a wider minimum hopping channel bandwidth will permit greater throughput of information without increasing the potential for interference. We continue to believe it is desirable to increase the hopping channel bandwidth. Increasing this bandwidth will allow frequency hopping systems to spread their transmitted power over a large frequency range and hence decrease the potential for interference to

other users. At the same time, the wider bandwidths will provide opportunities for new kinds of equipment to operate under these rules. For example, the wider bandwidths will allow operation of equipment such as wireless local area networks that depend on high speed transmission of data. Accordingly, we are increasing the maximum channel bandwidth limit for frequency hopping systems using the 902-928 MHz band from 25 kHz to 500 kHz. We are not implementing Gambatte's recommendation of a 1 MHz bandwidth for the 902-928 MHz band because this band contains too little spectrum to provide for a sufficient number of hopping channels. We are, however, increasing the maximum channel bandwidth for systems using the 2400-2483.5 MHz and 5725-5850 MHz bands from 25 kHz to 1 MHz. We believe the 1 MHz channel bandwidth for the 2400-2483.5 MHz and 5725-5850 MHz bands can be tolerated because the amount of spectrum available for hopping is considerably greater than for the 902-928 MHz band. Systems employing this much wider bandwidth can be expected to be operated with substantially reduced risk of interference.

20. To accommodate a 500 kHz channel bandwidth in the 902-928 MHz band we are decreasing the minimum number of hopping frequencies in that band from 75 to 50. Sufficient spectrum is available in the two higher frequency bands that there is no need to reduce the number of hopping frequencies below the current requirement of 75 in those bands.

21. The commenting parties are divided as to whether the present hopping channel occupancy times should be changed. California Microwave favors the 100 millisecond occupancy time per 5 second interval that was proposed in the *NPRM* for frequency hopping systems operating in the 902-928 MHz band and stated that the proposed 5 second averaging time for channel occupancy is a reasonable reduction from the previous 30 second requirement. However, most of the other respondents oppose changing the present occupancy time of 400 milliseconds and measurement interval of 30 seconds. Metricom and others argue that an occupancy time shorter than the present 400 milliseconds would in some cases increase the potential for a frequency hopping system to cause interference to other systems using the band. Metricom observes that certain packet systems broadcast a lengthy addressing protocol with each message. Such systems could conceivably complete their transmissions within the 400 millisecond interval presently allowed if the information message was short. However, Metricom states that these same systems would be forced to spread the information over many packets, each one including a high-overhead addressing protocol, if the occupancy time is reduced to 100 milliseconds.

22. The channel occupancy time of a frequency hopping system is also related to its hopping rate. The proposed maximum occupancy time of 100 milliseconds and 5 and 7.5 second measurement intervals would also indirectly mandate a minimum hopping rate of 10 hops per second. SCS recommends that we establish a minimum hopping rate of 100 hops per second in order to prevent any possible interference with video systems that may be using these frequencies. NYNEX requests that the Commission impose no hopping rate higher than the 2.5 hops per second implied in the current rules. It argues that each time a transmission hops to a new frequency, there is a transition, or adjustment, period before the information portion of the transmission can begin. According to NYNEX, there are ways of minimizing this problem, but they are complex and costly to implement.

23. We are not implementing our proposal to reduce the channel occupancy time from 400 milliseconds to 100 milliseconds, nor are we changing the implied hopping rate. We have concluded that such a change would yield only a minor reduction in interference potential. This minor benefit is outweighed, as pointed out by Metricom, by the increased interference potential inherent in forcing packetized frequency hopping data transmission systems to use a longer transmission time for the same message. We are, however, changing the interval over which channel occupancy is measured in the 902-928 MHz band from 30 seconds to 20 seconds to be consistent with the change in the minimum number of hopping channels in this band discussed above.

24. Metricom, OCI and NYNEX are concerned that the proposed rule that each hopping frequency must be selected at least once in the hopping sequence before it repeats would preclude many of the systems currently under development. For example, they submit that some systems are being developed that use combinations of multiple transceivers and operate in accordance with the following design. All of the units that are operating in the receiving mode hop through the same sequence of frequencies, but do not hop in synchronization with one another so that they can be addressed individually. As a unit that is operating as a transmitter shifts from communicating with one receiving unit to another, it may have to shift to a position in its own hopping sequence where it will be in synchronization with the target unit. Thus, some of the frequencies on the transmitting unit's hopping sequence list will not be selected and some may be selected more than once during the brief period immediately following the shift. However, on the average, each frequency in the hopping sequence will have an equal probability of selection. Metricom states that the rule should allow the determination of whether the hopping sequence requirement is met to be made either at the transmitting or receiving unit. Alternatively, Metricom suggests that the determination should be made for a single communicating transmitter/receiver pair. OCI and NYNEX advocate that we revise the proposed rule to state that each hopping frequency must be used equally by the system as a whole, and, on the average, by each unit acting as a transmitter within the system.

25. In view of Metricom's, OCI's, and NYNEX's statements about the manner in which systems using multiple transceivers may need to operate, we conclude that the most desirable way to regulate the use of hopping sequences is to specify that each frequency must be used equally on the average by each unit operating as a transmitter. We do not believe the potential for interference will increase if frequencies are selected more than once without repeating so long as each frequency has an equal likelihood, on average, of being selected. Notwithstanding this change, we want to make it clear that we are not allowing averaging over several transmitters in a networked system because we have no means to control how transmitters may be grouped into networks. We are concerned that in such systems certain sub-groupings of the transmitters and receivers that communicate frequently with each other might favor certain frequencies and thus increase the potential for interference.

26. Several commenting parties' discussion of general receiver and system issues relating to processing gain are applicable to frequency hopping systems. The majority of commenting parties mentioning receiver performance standards for frequency hopping systems state that such standards are irrelevant and unnecessary. Microlor and OCI, however, maintain that the concept of system robustness is important and urge the Commission to treat frequency hopping transmitters and receivers as a *system*. Telesystems notes that a receiver specification is necessary to promote spectrum efficiency. We agree that it is necessary to treat frequency hopping transmitters and receivers as a system in order to ensure that the spectrum efficiencies made possible through true spread spectrum operations are in fact achieved. We therefore are specifying certain basic standards for frequency hopping receivers. Receivers intended for use with frequency hopping systems will be required to have an input bandwidth that matches the hopping channel bandwidth of the associated transmitter and will be required to hop in synchronization with the transmitter. Frequency hopping systems meeting the minimum hopping channel requirements may have the capability of achieving processing gains of 15 to 19 dB if messages are sufficiently long to utilize all of the hopping channels.

27. Consistent with these new receiver standards, applications for certification of Part 15 frequency hopping spread spectrum transmitters will be required to describe the characteristics of the associated receiver or receivers in order for the Commission to determine that the required degree of processing gain is present and that the transmitter is indeed part of a true spread spectrum system. We are concerned that there is potential for abuse by applicants who might choose to market a less expensive receiver which does not deprocess the transmitted signal, instead of the receiver described in their application. We therefore intend to monitor receivers marketed for use with Part 15 frequency hopping systems and will consider further regulatory action if it becomes apparent that our intent of fostering spectrum-efficient systems and avoiding harmful interference is being subverted.

28. *Out-of-Band Emissions.* Both OCI and Utilicom express concern that the present requirement for direct sequence systems to reduce out-of-band emissions by 20 dB unduly penalizes systems that use less power than the maximum permitted 1 Watt or that spread the energy broadly over the entire band. They contend that this requirement is even more stringent than the out-of-band emissions limits for systems operating under other Part 15 rules, in particular, Section 15.209(c) of our rules.[7]

29. In response to OCI's and Utilicom's concerns, we are modifying our out-of-band emissions limit for Part 15 spread spectrum systems. The Commission did not intend to require these systems to limit their out-of-band emissions to levels below those required of other Part 15 devices. That is, it did not intend to require the level of unwanted emissions from spread spectrum systems to be suppressed below the levels permitted for the fundamental emissions of other Part 15 intentional radiators. The basic requirement will remain for 20 dB suppression of out-of-band emissions. However, we are modifying Section 15.247 to provide that out-of-band emissions for spread spectrum systems need not be suppressed below the 20 dB limit or the general requirements for other Part 15 devices set out in Section 15.209, whichever results in lesser attenuation.

30. *Directional Antennas.* Micrilor proposes that the allowed power levels for systems using directional antennas be reduced by the maximum of the antenna gain relative to an isotropic radiator. Other commenting parties endorse this proposal, and express concern that the risk of interference to other services would increase if spread spectrum systems were allowed to increase their effective radiated power by employing directional antennas. We agree with the commenting parties that the increased risk of interference due to use of high-gain directional antennas is a serious concern. Accordingly, we are limiting the use of directional antennas with these systems. Directional antennas with up to 6 dBi directional gain will be allowed on the transmitting units without penalty. 6 dBi is equivalent to the maximum gain which is practically realizable with a simple vertical antenna that is omnidirectional in the horizontal plane. However, if antennas of directional gain greater than 6 dBi are used on the transmitting units, the maximum peak output power must be reduced in dB by the amount that the directional gain of the antenna exceeds 6 dBi.

31. *Hybrid Systems.* We observe that the present rules do not explicitly specify the standards to be used for hybrid systems that use both direct sequence and frequency hopping techniques. To rectify this situation we are clarifying the rules as follows. Hybrid systems that employ a combination of both direct sequence and frequency hopping modulation techniques shall achieve a processing gain of at least 17 dB from the combined techniques. The frequency hopping operation of the hybrid system, with the direct sequence operation turned off, shall have an average time of occupancy on any frequency not to exceed 0.4 seconds within a time period in seconds equal to the number of hopping frequencies employed multiplied by 0.4. The direct sequence operation, with the frequency hopping operation turned off, shall have a maximum allowable spectral power density of 8 dBm in any 3 kHz bandwidth. These values were chosen to be consistent with the rules for frequency hopping and direct sequence system and to preclude the possibility of degenerate hybrid systems that might have higher interference potential than allowable frequency hopping or direct sequence systems.

32. *Transition Provisions.* We realize that industry will require some time for the transition to the new rules to reduce the economic impact for systems under development and currently in production. We also observe that the existing transition provisions in Section 15.37 will automatically apply to the rule changes adopted herein. We believe that the dates specified in Section 15.37 provide ample time for adjustment to the new rules because these rules generally represent a relaxation of existing standards and new standards intended to clarify qualifying criteria. We observe that several commenting parties were concerned about the restricted band requirements of Section 15.205 and the conducted limits of Section 15.207. These requirements would have gone into effect according to the schedule in Section 15.37 regardless of the outcome of this proceeding, however, and are beyond the scope of this proceeding.

FINAL REGULATORY FLEXIBILITY ANALYSIS

33. Pursuant to the Regulatory Flexibility Act of 1980, the Commission's final analysis is as follows:

I. Need and purpose of this action:

This Rule Making clarifies the intent and application of the present Part 15 spread spectrum rules and responds to the numerous inquiries made to the Commission by industry over the past several years. The rule changes are expected to aid industry in the design and implementation of spread spectrum systems by giving them clear and reasonable guidelines for the selection of the design parameters for these systems. The rule changes will reduce the Commission's workload by eliminating many of the inquiries that the Commission now receives concerning spread spectrum systems.

II. Summary of issues raised by the public comments in response to the Initial Regulatory Flexibility Analysis:

No commentors responded to issues raised in the Initial Regulatory Flexibility Analysis.

III. Significant alternatives considered and rejected:

The Commission considered all of the alternatives proposed in the NPRM and all timely filed comments directed to the various issues in the NPRM. The only significant alternative available to the Commission would be to maintain the status quo and not adopt these rules. However, this would not be to the advantage of either industry or the general public, since it would offer industry no clear guidelines on how final system designs could be achieved without causing interference to other communications systems.

ACTIONS

34. The Secretary shall cause a copy of this Report and Order, including the Final Regulatory Flexibility Analysis, to be sent 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. 601 et. seq., (1981)).

35. Accordingly, IT IS ORDERED that under the authority contained in Sections 4(i), 4(j), and 303(r) of the Communications Act of 1934, as amended, Parts 2 and 15, ARE AMENDED, as set forth in Appendix B below effective **August 24, 1990.** IT IS FURTHER ORDERED that this proceeding IS TERMINATED.

FEDERAL COMMUNICATIONS COMMISSION

Donna Searcy
Secretary

APPENDIX A

I. LIST OF THE PARTIES RESPONDING WITH COMMENTS AND REPLY COMMENTS

PARTIES RESPONDING WITH COMMENTS

1. Agilis Corporation	(Agilis)
2. APCO	(APCO)
3. Apple Computer, Inc.	(Apple)
4. American Telephone and Telegraph Co.	(AT&T)
5. Boston Edison	(Boston Edison)
6. California Microwave, Inc.	(California Microwave)
7. CYLINK	(CYLINK)
8. Gambatte, Inc.	(Gambatte)
9. Harris, Corp., Farinon Division	(Harris)
10. Metricom, Inc.	(Metricom
11. Micrilor, Inc.	(Micrilor)
12. NCR Corporation	(NCR)
13. NYNEX Corporation	(NYNEX)
14. O'Neill Corporation, Inc.	(OCI)
15. Pacific Gas and Electric Company	(Pacific Gas & Electric)
16. PA Consulting Group	(PA Consulting)
17. SCS	(SCS)
18. Telesystems SLW Inc.	(Telesystems
19. Southern California Edison Company	(So. Cal. Edison)
20. Utilicom, Inc.	(Utilicom)
21. Utilities Telecommunications Council	(UTC)

PARTIES RESPONDING WITH REPLY COMMENTS

1. Apple Computer, Inc.	(Apple)
2. American Telephone and Telegraph Co.	(AT&T)
3. Gambatte, Inc.	(Gambatte)
4. Metricom, Inc.	(Metricom)
5. Motorola, Inc.	(Motorola)
6. NCR Corporation	(NCR)
7. NYNEX Corporation	(NYNEX)
8. O'Neill Corporation, Inc.	(OCI)
9. Omnipoint Data Company	(Omnipoint Data)
10. Salient Communications Co.	(Salient Communications)
11. Sperry Marine, Inc.	(Sperry Marine)
12. Telesystems SLW Inc.	(Telesystems)
13. Utilicom, Inc.	(Utilicom)
14. Utilities Telecommunications Council	(UTC)

APPENDIX B

A. Title 47 of the Code of Federal Regulations, Part 2, is 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(c) is amended by adding the following definition in alphabetical order to read as follows:

Section 2.1 Terms and definitions

* * * * *

Pseudorandom Sequence. 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.

* * * * *

3. Section 2.1033 is amended by adding a new paragraph (b)(11), to read as follows:

Section 2.1033 Application for certification.

* * * * *

(b) * * *

(11) Applications for the certification of direct sequence spread spectrum transmitters under Part 15 shall be accompanied by an exhibit demonstrating compliance with the processing gain provisions of Section 15.247(e) of this chapter. Applications for the certification of frequency hopping transmitters under Part 15 shall be accompanied by an exhibit describing compliance of the associated receiver or receivers with Section 15.247(a)(1) of this chapter.

* * * * *

Title 47 of the Code of Federal Regulations, Part 15, is amended as follows:

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

Authority: Sec. 4, 302, 303, 304, and 307 of the Communications Act of 1934, as amended, 47 U.S.C. Sections 154, 302, 303, 304, and 307.

2. Section 15.203 is amended by revising the fourth sentence to read as follows:

Section 15.203 Antenna requirement

* * *

This requirement does not apply to carrier current devices or to devices operated under the provisions of Sections 15.211, 15.213, 15.217, 15.219, or 15.221.

* * *

3. Section 15.247 is amended by revising paragraphs (a)(1), (b) and (c) and by adding new paragraphs (d), (e), and (f) to read as follows:

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

(a) * * * * *

(1) Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the 20 dB bandwidth of the hopping channel, whichever is greater. The system shall hop to channel frequencies that are selected at the system hopping rate from a pseudorandomly ordered list of hopping frequencies. Each frequency must be used equally on the average by each transmitter. The system receivers shall have input bandwidths that match the hopping channel bandwidths of their corresponding transmitters and shall shift frequencies in synchronization with the transmitted signals.

(i) Frequency hopping systems operating in the 902-928 MHz band shall use at least 50 hopping frequencies. The maximum allowed 20 dB bandwidth of the hopping channel is 500 kHz. The average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 20 second period.

(ii) Frequency hopping systems operating in the 2400-2483.5 MHz and 5725-5850 MHz bands shall use at least 75 hopping frequencies. The maximum 20 dB bandwidth of the hopping channel is 1 MHz. The average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 30 second period.

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(b) The maximum peak output power of the transmitter shall not exceed 1 Watt. If transmitting antennas of directional gain greater than 6 dBi are used, the power shall be reduced by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

(c) In any 100 kHz bandwidth outside these frequency bands, the radio frequency power that is produced by the modulation products of the spreading sequence, the information sequence and the carrier frequency shall be either at least 20 dB below that in any 100 kHz bandwidth within the band that contains the highest level of the desired power or shall not exceed the general levels specified in Section 15.209(a), whichever results in the lesser attenuation. All other emissions outside these bands shall not exceed the general radiated emission limits specified in Section 15.209(a).

(d) For direct sequence systems, the transmitted power density averaged over any 1 second interval shall not be greater than 8 dBm in any 3 kHz bandwidth within these bands.

(e) The processing gain of a direct sequence system shall be at least 10 dB. The processing gain shall be 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.

(f) Hybrid systems that employ a combination of both direct sequence and frequency hopping modulation techniques shall achieve a processing gain of at least 17 dB from the combined techniques. The frequency hopping operation of the hybrid system, with the direct sequence operation turned off, shall have an average time of occupancy on any frequency not to exceed 0.4 seconds within a time period in seconds equal to the number of hopping frequencies employed multiplied by 0.4. The direct sequence operation of the hybrid system, with the frequency hopping operation turned off, shall comply with the power density requirements of paragraph (d) of this Section.

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FOOTNOTES

[1] More specifically, the processing gain of a spread spectrum system is the signal to noise improvement which the system is able to achieve, upon reception of its signal, over a system that employs no bandwidth spreading. For direct sequence systems, it is directly related to the rate at which the spreading code is generated; for frequency hopping systems, it is a direct function of the number of hopping channels over which the transmitted information is being spread. Hence, the processing gain provided by these systems is directly related to the spreading bandwidth.

[2] Minimizing the potential for interference to narrowband transmission systems operating within the same bandwidth requires that the signal be spread uniformly over the transmission bandwidth. The uniformity of the spreading is a function of the spreading code, i.e., the number of bits or channels in the code. The spreading code used must be long enough to ensure that the energy of the signal is distributed evenly over the transmitted bandwidth.

[3] *See First Report and Order* in GEN Docket No. 81-413, 101 FCC 2d 419 (1985). The Part 15 spread spectrum rules were recodified and clarified in the recent *First Report and Order* in GEN Docket No. 87-389, 4 FCC Rcd 3493 (1989). *See* 47 CFR Section 15.247.

[4] *See Notice of Proposed Rule Making* in GEN Docket No. 89-354, 4 FCC Rcd 6370 (1989).

[5] *See* 47 CFR Sections 15.3 and 15.7.

[6] We recognize that, for systems employing the full available spectrum at 902-928 MHz, this could result in a total measurement time of 2.5 hours, with longer scan times for the two higher frequency bands. However, we believe the 1 second time is necessary to be sure the limit is met while the system goes through its various transmission cycles. Also, because many systems use only a portion of the available spectrum, the complete scan time will often be considerably less.

[7] *See* 47 CFR Section 15.209(c).