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

In the Matter of	)	
Amendment of Part 15 of the Commission's Rules Regarding Spread Spectrum Devices	)	ET Docket No. 99-231
Wi-LAN, Inc. Application for Certification of an Intentional Radiator Under Part 15 of The Commission's Rules	)	DA 00-2317

COMMENTS OF APPLE COMPUTER, INC.

Apple Computer, Inc., ("Apple") hereby submits comments in response to the Commission's Further Notice of Proposed Rule Making and Order ("FNPRM") in this docket.[1] Apple applauds the Commission's continued efforts to remove regulatory and technical barriers that stymie technical innovation and stifle markets. Apple believes that the Commission's proposals will spawn new growth in markets for unlicensed devices. While Apple supports the intent of the Commission's proposals, it believes that a fine-tuning of certain aspects of those proposals will decrease the likelihood for interference while maintaining the greater design flexibility the Commission proposes to provide.

BACKGROUND

Apple is a leading developer and manufacturer of computer equipment, peripherals and networking systems. In addition to Apple's well-known computers such as the iBook, iMac, and

[1] *Amendment of Part 15 of the Commission's Rules Regarding Spread Spectrum Devices*, 16 FCC Rcd 10036 (2001).

PowerMac G4, Apple is also committed to producing cost-effective, broadband wireless connectivity and networking solutions. For example, the Apple AirPort, based on 802.11b technology, allows multiple Apple computers to be networked without cabling and provides broadband, high-speed Internet connectivity as well.

With the introduction of AirPort technology, Apple maintains a strong interest in unlicensed technology. Apple closely monitors development of new unlicensed devices and the use of unlicensed spectrum and has a keen interest in the outcome of the Commission's proposals, whether they relate to frequency hopping spread spectrum ("FHSS") systems, direct sequence spread spectrum ("DSSS") systems or to proposed digital transmission systems ("DTS").[2]

DISCUSSION

Apple fully supports the Commission's intent – to ensure the continued growth of the Part 15 unlicensed device markets. A key element for successful Part 15 markets is the Commission's willingness to liberalize its rules as technology advances. Yet that success also depends on the Commission's willingness to adopt rules that permit the coexistence of multiple technologies in shared spectrum. Apple's proposal revisions, as explained below, are designed to assist the Commission in crafting rules that will continue to stimulate technology development and competition in the manufacture of Part 15 devices.

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[2] Apple and twelve other major entities were parties to the *Joint Petition For Clarification or, in the Alternative, Partial Reconsideration* (filed October 25, 2000) ("*Joint Petition*"), which the Commission acknowledges as prompting its adoption of the FNPRM. *See* FNPRM at ¶ 9. Petitioners requested that the Commission clarify its rules to state that FHSS systems with bandwidths of 1 MHz or less could use reduced hop sets with as few as 15 hopping channels. The petition stated that the output power of such devices should be limited to 125 mW and that adaptive hopping techniques should be used. *See Joint Petition* at ¶ 25.

Frequency Hopping Spread Spectrum Systems

Minimum Number of Hopping Channels/Minimum Bandwidth. The Commission has proposed to amend 47 C.F.R. §15.247 to incorporate the changes regarding FHSS systems as requested in the Joint Petition. Specifically, it proposes to permit as few as fifteen hopping channels, regardless of bandwidth, provided that the device's output power does not exceed 125 mW and that adaptive hopping techniques are used.[3] Apple strongly supports this proposal.[4]

The current Commission rules permit FHSS systems in the 2.4 GHz band to use as few as 15 frequency-hopping channels, but require that the total frequency span of the hopping channels be at least 75 MHz. The 2.4 GHz unlicensed band is 83.5 MHz wide, thus allowing only 8.5 MHz of "frequency margin" for FHSS systems, both to avoid interfering with frequency static DSSS networks and to hop around each other. Essentially, as Apple and others have stated previously, this requirement bars the use of intelligent selection of hopping frequencies, despite the fact that the Commission's rules already permit it.[5]

As explained in the Joint Petition, the practical use of intelligent hopping algorithms can significantly improve the performance of FHSS systems that are operated in the vicinity of other 2.4 GHz band users as well as reduce the potential for their interfering with other spectrum users.

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[3] FNPRM at ¶ 13.

[4] While Apple supports the Commission's primary proposal wholeheartedly, the Commission did ask whether alternatives exist. Specifically, the Commission requested comment on whether even fewer hops could be used with a corresponding reduction in power. Apple believes the foregoing is a viable alternative. Here is why: Section 15.249 provides for low power operation of unlicensed devices without the restrictions placed on devices operating in accordance with Section 15.247. Accordingly, a device that complies with Section 15.249 could be configured as a "one hop" device. If the Commission adopts its 15 hopping channel/125 mW output power proposal, it might also consider going a step beyond by further reducing hop set frequencies – to between one and fifteen, with a corresponding linear reduction in maximum output power. The maximum output power could vary between the Section 15.249 level and the proposed 125 mW level.

[5] *See* 47 C.F.R. § 15.247(h).

When a FHSS system transmits on a frequency in use by either a DSSS system or another FHSS system, errors in data reception by the other systems' receivers may occur.[6] Systems that detect errors will cause the data to be retransmitted. This process results in the interfered-with DSSS or FHSS system occupying frequencies for a longer time period than would be required had the FHSS system originating the transmission been able to select an unoccupied frequency. The result of this inefficient process is a reduced data rate for affected systems *and longer frequency occupancy than otherwise would be necessary.* In addition, because the interfered-with DSSS and FHSS systems must transmit for a longer period of time, the probability that they will continue to be interfered with increases.[7] The remedy is to allow intelligent selection of hopping frequencies as the Commission has proposed.

Mandatory Adaptive Hopping. The Commission should encourage strongly, but not mandate, that technology developers use sound methods to intelligently select hopping frequencies to avoid interference. Apple believes that developers of FHSS technology (such as Bluetooth) already have a strong incentive to implement products that employ intelligent frequency hopping. The reason is simple: it is in their self-interest to avoid interfering with other Part 15 devices. For example, users may find that it is beneficial to operate both an IEEE 802.11b-based DSSS device and a FHSS device in the same environment.[8] If the FHSS device is

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[6] The extent to which errors occur will depend on the relative power levels and physical locations of systems' transmitters and receivers.

[7] *Joint Petition* at ¶ 13. A hypothetical example of this scenario is provided in paragraph 14 of the *Joint Petition*. In addition, there is precedent for the rule change proposed in the FNPRM. In the 902-928 MHz unlicensed band the Commission allowed a reduction in the minimum number of hopping channels for the same reason it should do so in the 2.4 GHz unlicensed band – to reduce the interference potential in the band so that unlicensed devices using different technologies can co-exist. *See Amendment of Parts 2 and 15 of the Commission's Rules Regarding Spread Spectrum Transmitters*, 12 FCC Rcd 7488, 7503 ¶ 27 (1997) ("*1997 Spread Spectrum Order*").

[8] 802.11b (DSSS) and Bluetooth (FHSS) devices could complement each other. Bluetooth devices might be considered suitable for short-range applications such as low data-rate cable replacement (for

unable to avoid interference to already-installed, co-located IEEE 802.11b devices, it may not be accepted.[9]

Another reason not to mandate adaptive hopping is that there are ongoing efforts to study various adaptive hopping algorithms. For example, this matter is the subject of a number of papers in the IEEE's P802.15 Working Group for Wireless Personal Area Networks. It may be that different algorithms may be suitable for different 2.4 GHz device applications.[10] Consequently, because analyses continue, it is premature to specify any one, mandatory algorithm to accomplish adaptive frequency hopping. Apple also believes it would be premature to determine a compliance testing method since the testing methodology could depend on the algorithm chosen.

On a related matter, the Commission should clarify that device designers have the flexibility to employ a variety of methods to implement intelligent hopping. For example, a device that "sniffs" RF spectrum over the air to determine occupancy is one way to accomplish "adaptive" hopping.[11] But it is also possible to employ higher-level, intelligent hopping techniques. Intelligent hopping does not imply that a system will park in one location and

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example, synching a laptop to a PDA without cables), while 802.11b devices might be considered more suitable for wider area networking applications (for example, networking several computers in a household with no need for wiring).

9 This is particularly true because there are quite a number of 802.11b-based devices already in the field, whereas FHSS-based Bluetooth devices are only beginning to come to market.

10 For more information on adaptive hopping algorithms, see http://www.ieee802.org/15/pub/TG2.html.

11 In this regard, Apple does not support the 30-second "hop set re-determination" requirement that the Commission proposes in its new rules. Much like adaptive hopping algorithms, there are different methods to intelligently modify hop sets. Apple believes that specifying a specific time interval implies using a specific method for hop set reassessment. A rigid time interval could lead to more overhead in data transmission and, therefore, lower data rates and increased probability of interference due to the fact that devices will transmit for longer periods. The interval for re-evaluating hop sets is best left as a design decision – noting that designers have every incentive to modify hop sets in the most efficient and least obtrusive manner possible.

occupy all available frequencies.[12] It is not a stretch of the imagination to envision an unlicensed network that intelligently hops its own frequencies to minimize its random access of frequencies available to all band users. For example, intelligence required by a network's transmitters could be sent over a wired network shared by systems, or where the systems reside on a common platform, by more direct means. This may reduce the need to use over-the-air frequencies to provide hopping intelligence to devices that are part of a system.

The Commission's use of the term "system" in Section 15.247(h) is not clearly defined. For example, the rule states that a "system" can incorporate intelligence to recognize other spectrum users and avoid them. Yet it also states that coordination of frequency hopping systems for the purpose of avoiding simultaneous occupancy of individual hopping frequencies by multiple transmitters is not permitted. However, a single "system" could consist of a master base station that controls multiple slave stations. Obviously, to the extent that the master base station can prevent its slave stations from attempting to simultaneously occupy the same frequencies, data retransmissions could be reduced and there would be greater spectrum efficiency. The alternative is to let the system's slaves compete randomly with non-system devices. This leads back to a greater probability of random frequency "collisions" within a given environment.

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[12] The Commission expressed a concern that a number of frequency hopping spread spectrum transmitters could locate in one area, coordinate frequencies among them selves and thereby close-out other users. *See, e.g., 1997 Spread Spectrum Order* at 7512 ¶ 46 n. 107 (1997). However, this is unlikely to occur, particularly at 2.4 GHz. First, substantially more spectrum is available (83.5 MHz vs. 26 MHz). Second, LAN nodes (and Bluetooth) tend to cluster on single frequencies or single hop sequences to communicate with a common base station or with each other (which is not possible using different frequencies or hop sequences). Therefore, the hypothetical situation described in the Commission's *1997 Spread Spectrum Order* is not likely to occur unless there are numerous 2.4 GHz nodes transmitting without listening to one another or to a common access point. In addition, with the practical powers levels that are likely to be implemented, it is unlikely that the number of transmitters necessary to completely occupy the band would be clustered closely enough to interfere with each other.

Because these other forms of adaptive hopping can satisfy the Commission's spectrum occupancy concern while improving spectrum sharing and efficiency, Apple proposes to revise the language of Section 15.247(h)[13] to clarify that a range of intelligent hopping methods can be employed. Apple's proposed revision appears in the attached Appendix.

Alignment with U-NII Rules

The Commission notes that, if adopted, its proposals would move Section 15.247 into closer alignment with its U-NII rules.[14] Therefore, it asks if the substance of its proposals could be achieved by simply amending the U-NII rules to include the 915 MHz and 2.4 GHz bands.

Apple believes that the immediate thrust of the Commission's rule changes should focus on changes needed to allow new devices ready for marketing to proceed without unnecessary technical barriers. Consequently, before consolidating the U-NII and the Section 15.247 rules, Apple believes the Commission should embark on a thorough analysis of the specific rule changes required and an explanation of what it believes the effect of those changes would be. For now, there are more immediate issues at hand.[15] Because the scope of the Commission's suggestion is not clear, Apple believes the matter should be left for future consideration.

In addition, the Commission seeks comment on whether the upper limit of the U-NII band should be extended from 5825 MHz to 5850 MHz.[16] That would align the U-NII band with the Section 15.247 5 GHz band. Apple believes that if adopted, the Commission's DTS proposal

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[13] Section 15.247(h) is re-designated as Section 15.247(g) in the Commission's FNPRM. However, there are no textual changes.

[14] *See* 47 C.F.R. 15, subpart E.

[15] For example, the U-NII rules do not specify parameters for FHSS systems as proposed in the NPRM.

[16] FNPRM at ¶ 18.

would incorporate any U-NII system implementations. Therefore, Apple does not oppose the band alignment.[17]

Digital Transmission Systems

The Commission proposes to modify Section 15.247 to accommodate new digital transmission systems ("DTS") that have characteristics similar to spread spectrum systems and that comply with the Commission's spread spectrum rules, but that are not true spread spectrum systems.[18] Apple supports this proposal, as its adoption is critical to future innovation and use of the 2.4 GHz band.

However, the Commission should make minor revisions to its proposal to ensure it does not inadvertently cause increased interference in the 2.4 GHz band. Apple's specific concern is that the Commission proposes to adopt for DTS devices the same maximum transmitter output power limit and peak power spectral density ("PSD") limit that apply to DSSS devices.

Because DTS devices will not be required to spread their signals, they will not be required to significantly spread their allowed power over an appreciable bandwidth. The following example using the AirPort 802.11b device and a maximum power DTS device illustrates the problem. Under the Commission's proposal DTS devices would be permitted to use a maximum of 1 watt transmitter output power and a corresponding PSD limit of 8dB/3 kHz (same as the existing DSSS limits).[19] Therefore, a 1 watt DTS transmitter could occupy a

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[17] However, we reiterate that the current U-NII rules do not necessarily incorporate Section 15.247 rules.

[18] FNPRM at ¶ 16.

[19] The current 8 dBm/3kHz specification has its genesis in a 1990 Commission Report and Order. *See Amendment of Parts 2 and 15 of the Rules with Regard to the Operation of Spread Spectrum Systems,* 5 FCC Rcd 4123 (1990) ("*1990 Spread Spectrum Order*"). In its *1990 Spread Spectrum Order*, the Commission declined to require direct sequence spread spectrum systems to use a specific pseudorandom spreading code as a means to ensure that systems actually spread their signals and thus

relatively narrow bandwidth (under 0.5 MHz) and pose a serious interference threat to existing 802.11b networks, unless a considerable separation distance is mandated.[20] The cure is to simply limit the maximum allowable PSD for DTS devices and to specify that PSD in units of dBm/MHz. This revision would eliminate approval of DTS devices that are narrowband interferers. One option for consideration is to harmonize the DTS PSD limit with the ETSI limit of 10 dBm/MHz.[21]

Direct Sequence Processing Gain

The Commission's FNPRM gives a good description of why the processing gain test is unnecessary. It was adopted long ago to ensure that the more liberal power levels afforded true spread spectrum devices where not taken advantage of by non-spread spectrum devices.[22] The idea was that devices exhibiting processing gain would necessarily spread their energy over a wide bandwidth - to limit their interference potential - and would be more resistant to interference as well. The Commission's goal was the correct one, but technological advance and the Commission's DTS proposal has obviated the need for the rule. Most importantly, if the

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pose less of an interference threat. Instead the Commission adopted the 8 dBm/3kHz power spectral density limit as an interference control. With regard to the 3 kHz bandwidth, the Commission stated: "We have chosen the 3 kHz bandwidth because it is convenient for measurement purposes. This is the standard swept-filter bandwidth on a spectrum analyzer." *Id. at* 4124 ¶ 12.

[20] Obviously, requiring by rule a minimum separation distance is contrary to the essence of the Commission's Part 15 rules.

[21] *See Electromagnetic compatibility and Radio spectrum Matters (ERM); Wideband Transmission systems; data transmission equipment operating in the 2,4 GHz ISM band and using spread spectrum techniques; Part 1: Technical characteristics and test conditions,* ETSI EN 300 328-1, V1.2.2 at § 5.2.2 (2000-07).

[22] FNPRM at ¶ 22.

Commission adopts its DTS proposal a device would not be required to spread its signal anyway. Thus one of the fundamental reasons for requiring processing gain in the first place disappears.[23]

Furthermore, the Commission itself has observed the difficulty of measuring true processing gain for certain types of digital modulations as well as the disagreement as to the definition of processing gain.[24] In other words, subverting the Commission's processing gain test is not difficult because it is possible to design a device to exhibit processing gain based on a certain test without using a true spread spectrum signal.

Part 15 manufacturers' survival depends in part on the ability to produce devices with low interference potential and high interference resistance. Manufacturers producing wireless local area network and wireless personal area network devices simply have no incentive to produce inferior products. Consequently, Apple supports removing the processing gain rule.

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[23] The administrative history of the Commission's spread spectrum proceedings reveals why the Commission adopted the processing gain requirement and, consequently, why it is no longer needed. In 1989, the Commission proposed a minimum 127 bit pseudorandom spreading code for direct sequence spread spectrum systems. *Amendment of Parts 2 and 15 of the Rules with Regard to the Operation of Spread Spectrum Systems*, 4 FCC Rcd 6370, 6371 ¶ 11 (1989). The Commission reasoned that requirement would ensure that systems actually spread their signals, thereby reducing the potential to interfere with other systems. The Commission also reasoned that the required code would result in a processing gain benefit, making the spread system more interference resistant. However, the Commission declined to require a specific code, instead adopting the current power spectral density limit to control interference. *See 1990 Spread Spectrum Order* at 4124-25 ¶ 13.

To afford a measure of interference resistance and as a check to make sure devices it authorized were actually spread spectrum devices, the Commission did adopt the current processing gain requirement. The Commission stated: "[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 is acceptable to the Commission as a spread spectrum system. *See id*. at 4125 ¶ 15.

[24] FNPRM at ¶20.

Interim Waivers For FHSS Systems That Meet the Commission's Proposed Rules

Apple supports the Commission's decision to grant interim waivers to new devices that conform to its proposed DTS rules. However, the same policy should be applied to applicants seeking authorization for new devices that conform to the proposed FHSS rules.

The industry is poised to develop new FHSS devices that will take advantage of the Commission's proposed rule changes. Providing the opportunity for new FHSS devices to be approved in advance of this proceeding's conclusion will encourage more rapid development of the technology and faster deployment of product. The more quickly these devices are deployed the more quickly the 2.4 GHz spectrum sharing environment improves. There is no reason to delay approval of new FHSS devices that will take advantage of the Commission's propose changes.

Consequently, Apple requests that during the pendency of this proceeding, the Commission waive the relevant parts of Section 15.247(a)(1)(iii) to permit authorization of FHSS devices that meet the new conditions of the Commission's proposals. In addition, Apple requests that the FHSS waiver policy be identical in substance to the DTS waiver policy stated in the FNPRM; that OET accept applications for equipment certification for reduced hopping channel FHSS systems that meet the other FHSS requirements proposed in the FNPRM.[25] As is the case for DTS devices, a formal waiver would not be required – only a statement that the device submitted for authorization meets the terms of the Commission's policy as to Section 15.247 FHSS waivers.

[25] FNPRM at ¶ 26.

CONCLUSION

A review of the administrative history of its Part 15 rules reveals that the Commission has consistently promoted technological advancement by declining to adopt overly restrictive Part 15 rules. In the FNPRM, the Commission upholds that tradition and is to be congratulated for its pro-competition, pro-technology stance. Apple believes that if the Commission's primary FNPRM proposals are adopted with minor revisions to further limit interference potential and increase technological flexibility, industry will be provided a regulatory environment that will permit more spectrum efficient and more innovative Part 15 products.

Respectfully submitted,

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Appendix

Proposed Rule Change

Authority: 47 U.S.C. 154, 302, 303, 304, 307 and 544A.

We propose to amend Title 47 of the Code of Federal Regulations, Part 15, as follows:

Section 15.247 is proposed to be amended by revising re-designated paragraph (g) to clarify that a variety of means can be used to employ intelligent frequency hopping.

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

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(g) The incorporation of intelligence within a frequency hopping system [or network] that permits the system [or network] to recognize other users within the spectrum band so that it chooses and adapts its hop sets to avoid hopping on occupied channels is permitted.