Before the
Federal Communications Commission
Washington, DC 20554

In the Matter of	)	
	)	
Amendment of Part 15 of	)	ET Docket No. 99-231
the Commission's Rules Regarding	)	
Spread Spectrum Devices	)	
	)	

Reply Comments of Lucent Technologies Inc.

In response to the Commission's Notice of Proposed Rulemaking regarding unlicensed spread spectrum devices,[1] Lucent Technologies Inc. (Lucent) submitted comments opposing the proposed Part 15 rule changes to increase the maximum bandwidth allowed for frequency hopping devices. Lucent also asserted that the existing compliance criteria for direct sequence systems are adequate, with the additional requirement as proposed by the Commission that a processing gain calculation be included for systems which have fewer than 10 chips per symbol. Lucent further opposed the proposed alternative Gaussian noise jamming test.

Lucent urges the Commission to consider carefully the benefits and costs associated with any rule changes before making a decision. In this particular instance, the costs associated with the proposed frequency hopping rule changes outweigh any purported benefits.

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[1] *See Amendment of Part 15 of the Commission's Rules Regarding Spread Spectrum Devices*, Notice of Proposed Rulemaking, ET Docket No. 99-231, FCC 99-149 (Notice).

Advocates of the frequency hopping rule changes assert that the proposed rules will enable frequency hopping devices to provide high-speed, broadband applications useful for schools and businesses and afford them "equal access" to the band.[2] One commenter also claimed that adoption of the proposed changes will enable manufacturers to build wideband frequency hopping (WBFH) products suitable for use on a global basis.[3] These commenters contend that there will be little or no negative consequences associated with the proposed changes.

Lucent strongly disagrees with their unsubstantiated claims for several reasons. First, Lucent disputes that rule changes are necessary. Proposed WBFH systems can provide no services that are distinguishable from existing direct sequence systems. In fact, existing direct sequence spread spectrum systems have been widely deployed in business and educational settings throughout the country, providing performance levels equal to or better than levels anticipated for WBFH devices, at lower costs, without the need for a rule change.[4] Over 200 thousand Network Interface Cards for direct sequence systems were shipped worldwide in 1998 alone.[5] Like direct sequence system customers, FH vendors have recognized the benefits of such systems and have added products based on 802.11 to their product portfolios in 1999.

Second, frequency hopping devices are not denied "fair access" to the band by the current rules. Rather, the rules explicitly allow frequency hopping devices to operate in the band. While present frequency hopping systems may not be able to match direct

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[2] *See* e.g. 2Wire Inc. comments.
[3] Proxim comments at 4.
[4] *See* Lucent comments at 2-3. *See also* IEEE Spectrum at 49-53, June 1999 edition; WaveWorld 3rd Quarter 1999 edition.

sequence system data rates without amendments to the rules, this does not necessarily render the rules unfair, because all parties were informed of the rules at the outset and the rules apply equally to everyone operating in the bands. The 802.11b specification required invention to achieve high data rates under the current rules. That specification has gained significant acceptance and recently won the PC Magazine award for Technical Excellence for Network Standards.[6] Future invention may also allow FH spread spectrum manufacturers to increase the data rate as well. Changing the rules at this time would disadvantage manufacturers who built their products to satisfy the current requirements and permit new devices, some of which may be outside the scope of the HomeRF proposal, to be deployed. This would create an uncertain environment for DS and narrowband FH devices and lack of standardization which could be detrimental to the growth of the market for these products.

Furthermore, changing the rules will not serve the public interest, because the WBFH proposal will create increased interference to existing FH and DS spread spectrum devices. In other words, any performance gains experienced by WBFH systems will come at the expense of FH and DS systems who have "played by the rules." Moreover, WBFH systems will undermine the infrastructure investment in the embedded base of FH and DS systems. Lucent, Local and Metropolitan Area Networks Standards Committee of the Institute of Electrical and Electronics Engineers (IEEE-LMSC), 3Com, Nokia, Aironet, and Intersil have provided extensive technical analysis demonstrating WBFH devices' increased interference levels, which have not been contradicted or refuted with competing

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[5] Wireless LAN Market Review and Forecast, 1998-2003, International Data Corporation, Figure 6.
[6] *See* PC Magazine Online, http://www.zdnet.com/pcmag/stories/reviews/0,6755,2390228,00.html.

technical studies. Devices that are compliant with the proposed rules but unanticipated by HomeRF could create even greater interference problems.

Finally, Lucent disagrees with the assertion that the proposed changes are consistent with non-U.S. regulations for frequency hopping devices. The proposed rules conflict with the rules of countries that follow CEPT Recommendation 70-03.[7] Annex 3 in Rec. 70-03 specifies that ETSI Standard ETS 300 238 is applicable for the use of Radio Local Area Networks (RLANs). Clause 5.1.1, "FHSS Modulation," of ETS 300 238 states that "FHSS modulation shall make use of at least 20 well defined, non-overlapping channels or hopping positions separated by the channel bandwidth as measured at 20 dB below peak power."[8] The proposed rules require 75 hopping frequencies. With a total bandwidth of 83.5 MHz and channel bandwidths of 3 and 5 MHz, the proposed changes will result in substantially overlapping channels, which will conflict with the requirements in ETS 300 238.

Furthermore, Rec. 70-03 specifies a maximum power of 100 mW e.i.r.p..[9] The proposed rules permit e.i.r.p. levels of 1280 mW for the 3 MHz channel and 800 mW for the 5 MHz channel. The proposed power levels are significantly higher than the Rec. 70-03 power level and typical power levels of deployed spread spectrum devices. As discussed in more detail below, permitting high power levels, *i.e.* more than 100 mW, will create increased interference. Thus, contrary to commenters' claims, the proposed rules

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[7] CEPT/ERC Recommendation 70-03 (Tromsø 1997), Relating to the Use of Short Range Devices (Rec. 70-03).

[8] European Telecommunications Standards Institute (ETSI) European Telecommunication Standard (ETS) 300 238, November 1996, second edition, Radio Equipment and Systems (RES); Wideband transmission systems; Technical characteristics and test conditions for data transmission equipment operating in the 2,4 GHz ISM band and using spread spectrum modulation techniques.

[9] Rec. 70-03, Annex 3 specifies e.i.r.p and the reference to row 11 of Table 2 specifies 100 mW.

are not consistent with international requirements and will not enable manufacturers to build products suitable for global platforms. Lucent responds to other technical comments filed in this proceeding as follows.

The Maximum Frequency Hopping Bandwidth Should Not Be Increased

Lucent continues to believe that the proposed increase in bandwidth will create unacceptable interference to existing spread spectrum systems. Lucent's position is supported by an extensive analysis conducted by the IEEE-LMSC.[10] Lucent's conclusions are also supported by comments filed by Intersil. In an extensive analysis and simulation, Intersil showed that the partially overlapping WideBand channels produce a "worst case" situation for limiter/discriminator receivers.[11] Nokia[12] and Aironet[13] reached these same conclusions backed by analysis and measurements. Intersil's studies also showed that the WBFH proposal causes considerable interference to Bluetooth devices, new devices likely to be used in homes that are designed to comply with existing rules.[14] Moreover, Intersil's simulation demonstrated that, in addition to posing an interference threat, WBFH devices will exhibit poor performance.[15]

The claims advanced by several commenters that the proposed linear power level decrease along with the increased bandwidth would compensate for any increased

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[10] *See* Letter from James T. Carlo to Magalie R. Salas, October 2, 1999, ET Docket No. 99-231, IEEE 802.11-99/239 (IEEE-LMSC Letter 1).
[11] Intersil comments filed September 7, 1999, Attachment "Analysis and Simulation of Overlapped Frequency Hopping Channels."
[12] *See* Nokia comments.
[13] *See* Aironet comments.
[14] Intersil comments filed September 29, 1999, Attachment "Effects of WBFH Interference on Bluetooth Receiver Reliability."
[15] Intersil comments filed October 4, 1999, Attachment "Simulation of WBFH Interfernce on Multipath Performance."

interference to other spread spectrum systems[16] were not substantiated by a thorough examination of the proposed rule changes. IEEE-LMSC was one of the few parties to supply technical support, including a generalized model of the interference scenario, for its positions. IEEE-LMSC found that the proposal will increase interference to existing spread spectrum devices and that power level reductions far in excess of those proposed would be necessary to alleviate the interference increases. The following summarizes the conclusion of the IEEE-LMSC analysis:

> It is shown that increasing the bandwidth of frequency hopping systems to 3 or 5 MHz greatly increases the interference to 1 MHz bandwidth frequency hopping packet data systems. The increase would require the WBFH system to use a power level as much as 20 dB below the 1 MHz system to offset the effect of the wider bandwidth alone. The potential increase in frequency hopping rate also produces a like factor.
>
> The effect on direct sequence packet data systems is less, but is nevertheless significant. It is shown that the change would cause a 13 to 15 dB effect on a packet data system such as one conforming to IEEE p802.11. That is, the WBFH power level would have to be decreased by 13 to 16 dB to have the same interference effect on this system as does a 1 MHz bandwidth frequency hopping system.[17]

The power differences referenced by IEEE-LMSC refer to ratios between the WBFH and victim systems; not to the ratio of the WBFH power to the maximum allowable. The IEEE-LMSC filing also noted that current systems use power levels considerably below the maximum power levels allowed. The power level limits proposed in the Notice, though reduced from the maximum levels now permitted, are nevertheless higher than the levels currently used.

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[16] *See* comments filed by Breezecom, Home Wireless Networks, and Micrilor.

[17] *See* Annex 1 of IEEE-LMSC Letter 1, Abstract

Aironet and Eastman Kodak (Kodak) acknowledged that the increase in bandwidth would create increased interference to existing spread spectrum systems and proposed to offset that increase through more drastic power reductions.[18] Both proposed to decrease power levels by the inverse of the bandwidth squared. Kodak also provided an alternative means of limiting interference by controlling the WBFH duty cycle. In addition, Aironet proposed a maximum power level of 100 mw for bandwidths greater than 1 MHz.

Lucent agrees with Aironet and Kodak that a power level decrease in excess of the proposed inverse linear relationship of the Notice is necessary to alleviate the added interference to existing spread spectrum systems. However, Lucent disagrees that a level proportional to the inverse square of the bandwidth is sufficient, even if Aironet's proposed 100 mw power limit is imposed.[19] This is based on a review of the IEEE-LMSC Annex 1, figure 3-3. In some cases even an inverse bandwidth cubed relationship is insufficient.[20] Thus, Lucent continues to believe that the proposed increase in frequency hopping bandwidth will create additional interference to existing spread spectrum systems and urges the Commission to retain the frequency hopping provisions of Section 15.247 of the Commission's Rules in its current form.

The Requirements for Direct Sequence Systems Should be Modified Only Slightly

Lucent reconfirms its position that the CW jammer test for all direct sequence systems with the added requirement of a mathematical processing gain calculation for systems with less than 10 chips per symbol is appropriate and that the Gaussian noise test is unnecessary. Other commenters, including Apple Computer, Glenayre Western

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[18] Aironet comments at 3; Eastman Kodak comments at 1.
[19] *See* Aironet and Eastman Kodak comments.

Mutliplex, IEEE-LMSC, Intersil, and the Wireless Ethernet Compatibility Alliance, agreed with Lucent that a Gaussian noise test should not be required.

Micrilor, however, asserted that the Gaussian noise test should be required for all systems with chip to symbol ratios less than 10 and that the CW jammer test should be an alternative only for systems with a chip to symbol ratio greater than or equal to 10.[21] Micrilor opposed use of the CW jammer test at low chip to symbol ratios because they claim a statistical anomaly will improperly permit a simple Binary Phase Shift Keyed (BPSK) system to pass.

Home Wireless Networks (HWN) claims that the CW jammer test understates the actual spreading gain by 5 dB.[22] Lucent agrees with HWN and Micrilor that the jammer test understates the spreading gain at low chip-to-symbol ratios. However, the variance depends on the spreading ratio and on the reference bit error rate. It is much less than 5 dB at 8 chips per symbol providing the restriction on the reference bit error rate, which Lucent proposed, are followed.[23] An 8 chip per symbol spreading ratio is used in the IEEE standard high speed 2.4 GHz Physical layer (PHY) standard.

The CW jammer test accomplishes the major intent of proving that the stated spreading ratio is accomplished and of assuring good quality systems are deployed. Further, the quality of the system is more dependent on system performance in actual environments than in how it performs in bench tests such as the spreading gain test. Systems conforming to the IEEE-LMSC standard high speed 2.4 GHz PHY have been

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[20] *See* Attachment.
[21] Micrilor comments Appendix 1-3.
[22] HWN second comments at 4 (October 4, 1999).
[23] Lucent comments, Attachment 2, page 7.

shown to exhibit superior performance in the noise and multipath conditions which actually exist. Further, this standard requires strict conformance to other quality assurance parameters. Any rules change now that would disqualify a system that meets the extensive quality requirements of this standard would be counter to the more important objective of assuring quality systems which make most efficient use of the valuable radio spectrum.

Lucent's suggested guidelines, including the definitions of “chip” and “symbol” and the restrictions on bit error rate,[24] should alleviate the Micrilor and HWN objections to the CW jammer test. Thus, Lucent continues to believe that a Gaussian noise test is unnecessary. However, if the Commission were to adopt a Gaussian noise test, the test should:

1. be a wideband noise test as outlined by Aironet[25] and
2. be accompanied by a detailed test procedure, as explained in Lucent's comments.

A wideband test is necessary to evaluate the full capability of the system. It is also more consistent with the basic spreading gain definition that requires a comparison of the S/N with the spreading on and off. Micrilor claims that the wideband test overstates the spreading for a wide bandwidth IF filter. However, the wide bandwidth IF filter would be present in a non-spread measurement, if this measurement could be made, and the difference would compensate.

Furthermore, the Commission would have to properly specify the test method for a Gaussian noise test requirement. Aironet proposed a specific means of conducting the wideband Gaussian noise test utilizing a spectrum analyzer, but neglected to account for

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[24] Lucent comments at 4 and Attachment 2, page 7.
[25] Aironet comments at 4.

many factors which could affect the measurement. Aironet's proposal properly applies a correction factor for bandwidth but does not account for log/linear averaging and voltage envelope versus power envelope averaging, nor does it specify the detection mode of the spectrum analyzer. Further, the Aironet bandwidth correction factor requires that the effective noise bandwidth of the receiver IF channel filter be known from the filter design or be empirically measured. It is assumed that the effective noise bandwidth refers to that defined in the HP application note cited in Lucent's comments.[26] The effective noise bandwidth is not normally specified for filters and will usually need to be empirically measured, leading to a further possibility of differences in measurement results. These illustrate the possible variations that would be encountered if the test method is not specified properly and completely.

Micrilor does not define how the noise is measured. Thus, all of the potential variations in results also apply to their proposed narrow band technique. Lucent continues to urge the Commission to avoid these complications by not adopting a Gaussian noise test.

Spread Spectrum Rules Should Not be Extensively Changed

HWN and Kodak filed comments asking for extensive changes in the spread spectrum rules. HWN proposed to replace the spreading rules altogether with a single Power Spectral Density (PSD) rule. Kodak suggested substituting the European

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[26] Hewlett-Packard, Application Note 1303, Spectrum Analyzer Measurements and Noise, available at http://www.tmo.hp.com/tmo/Notes/English/5966-4008E.html.

Telecommunication Standards Institute ETS 300-328 rules for the currently defined frequency hopping rules of 15.247.

Lucent opposes such extensive changes because they jeopardize the current standards for spread spectrum systems which have enabled the creation of interoperable products. Standards benefit the public interest because they foster competition for interoperable products and lead to more varieties of lower priced commercial and consumers products. For example, over the past 10 years, spread spectrum manufacturers have invested technological effort and expense to develop reliable systems that conform to the current rules. In addition, industry organizations have developed interoperability standards for these systems that conform to these rules. Amending the established rules now would essentially discard the standardization and interoperability efforts that have been conducted by the spread spectrum industry.

Standardization is particularly important for radio frequency systems because they are prone to random system diversification due to their susceptibility to spectrum coexistence conflicts. The current spread spectrum rules help alleviate spectrum coexistence conflicts. Contrary to their claims, HWN's proposed changes would hamper the acceptance and use of 2.4 GHz unlicensed systems. Moreover, the changes would lead to the deployment of non-interoperable systems that are likely to interfere with one another.

Specifically, HWN's proposal will create increased interference to current spread spectrum systems because, as shown below, they would permit systems, including WBFH systems, with power levels higher than those currently allowed and with power level limits that increase with bandwidth. HWN proposes to replace the spreading rules with a rule

limiting the PSD to 50 mw/MHz in accordance with the PSD definition of section 15.400 (the U-NII section).[27] This would limit the power level of frequency hopping systems in direct proportion to the bandwidth. For example, frequency hopping systems of 1 MHz bandwidth that comply with the current rules would be limited to 50 mw power and the 5 MHz bandwidth systems proposed in the Notice would be permitted 250 mw. This is counter to the proposal in the Notice, which proposes an inverse bandwidth relationship and the inverse relationship has been shown to be insufficient to equalize interference.

Increasing the Direct Sequence Processing Gain Increases Interference Susceptibility

Lucent demonstrated in its comments that increasing the spreading gain of direct sequence systems increases their susceptibility to interference. This refutes the HomeRF claim[28] that increasing the spreading gain helps combat interference. Commenters on both sides of the frequency hopping bandwidth question inappropriately accepted HomeRF's claim.[29] Thus, Lucent reiterates the facts shown in annex 1 to its comments:

> *Increasing the direct sequence spreading gain increases the probability of interference in general and increases that from frequency hopping systems in particular.*

The Lucent analysis considered the worst case scenario in which a very large region of interferers exists and showed that an increase in spreading gain increases interference in the general case. The increase in interference probability is even greater in a more limited deployment region size that is the typical deployment situation. This can be shown as follows.

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[27] HWN comments at 8

[28] Notice in paragraph 9.

[29] For example, Micrilor at 1 and Glenayre Western Multiplex at 3

Increasing the spreading gain lowers the required C/I ratio of the receiver and thus tends to reduce the number of interferers by lowering the range of interference, however this reduction does not overcome the effect of the increase in bandwidth over which interference occurs. This is true even for the infinite deployment area considered in the Lucent comments. Interference can be expected to occur at all frequencies in the 2.4 GHz band; this is, in fact, required when the interferer is a frequency hopper. Thus, the interference probability dependence on bandwidth is a direct linear relationship. In more limited deployment regions, the interference distance exceeds the boundary of deployment and the lowered range has little or no effect. Thus, the interference probability increase is directly proportional to the bandwidth in this usual deployment area size.

If the interferer were of lower bandwidth than the direct sequence system to begin with, and if in addition all interference was on the same frequency, then increasing the spreading bandwidth would help. This is clearly not the situation in the 2.4 GHz band, and in the unlicensed bands generally. Thus, Lucent reemphasizes its showing that increasing spreading gain increases the probability of interference for direct sequence systems.

Conclusion

Lucent urges the Commission to reject the proposed rules to expand bandwidth for frequency hopping devices, because such changes will create unacceptable interference to existing FH and DS systems. Lucent, IEEE-LMSC, Nokia and Intersil have clearly demonstrated that the increased bandwidth will cause additional interference to existing frequency hopping and direct sequence systems. Given this fact, any possible benefits associated with the frequency hopping rule changes are not warranted. Lucent also agrees with the Commission that for direct sequence systems with less than 10 chips per symbol,

a mathematical calculation demonstrating the required 10 dB processing gain should accompany the CW jamming test results. Finally, Lucent believes that the proposed alternative Gaussian noise jamming test should be excluded, until a detailed test procedure specifically designed for evaluating processing gain is developed. Inclusion of this test as an option without an accompanying test procedure invites inaccurate and widely variable test results.

Respectfully submitted,
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By_____

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ATTACHMENT

WBFH Power Difference to Compensate for Increased Interference to the IEEE Standard NBFH System

Aironet and Kodak, in their comments, proposed that the WBFH power level should be reduced by an inverse bandwidth squared relationship in order to compensate for the increased interference caused by the bandwidth increase. Annex 1 of the IEEE-LMSC comments is used here to investigate the sufficiency of this requirement.

Consider the WBFH power level to be related to an IEEE standard NBFH victim system power level by the following

$$P_{WB} = \frac{P_{NB}}{B_{WB}^{\ n}} \ .$$

In the equation, P_{WB} is the WBFH power level, P_{NB} is IEEE standard 2 Mb/s NBFH power level, B_{WB} is the WBFH bandwidth in MHz and n is an exponent. An exponent value of 2 corresponds to that recommended in the referenced comments and the value of 3 is used for comparison.

The IEEE-LMSC annex defines an interference factor dependent on the WBFH bandwidth and hopping rate. The interference factor for a 5 MHz bandwidth WBFH with slow frequency hopping was shown to be 3. However, higher hoping rates create higher probability of interference and another factor as high as 3 was shown to apply if the WBFH system operates at the fastest optimum hopping rate for packet data LANs. Thus, the factor was shown to be between 3 and 9 for packet data LANs. The lower value of 3 applies for slow frequency hopping.

Figure 3-3 of the IEEE-LMSC comments shows how the number of interfering devices in range of a victim receiver decreases as the interfering device power level is decreased. The table below is computed from the IEEE LMSC figure and compares the effect of an inverse bandwidth exponent of 2 and 3 on the interference factor.

Deployment area radius to cell radius ratio	Proportion of 5 MHz WBFH devices interfering at equal power level	Proportion interfering with reduced power level exponent = 2	Factor compensated at the proposed exponent = 2	Proportion interfering with reduced power level exponent = 3	Factor compensated at the higher exponent = 3
1.0	83%	50%	1.6	30%	2.7
1.5	83%	40%	2.1	20%	4.1
2.0	78%	28%	2.8	12.5%	6.2
2.5	72%	21%	3.4	8%	9.0
3.0	63%	15%	4.2	6%	10.5

The table shows the value of the interference factor of the IEEE-LMSC annex 1 which can be compensated by lowering the WBFH power level by an inverse bandwidth to the nth power relationship. The necessary factor reduction is between 3 and 9 depending on the frequency hopping rate. The table is computed from figure 3-3 of the IEEE-LMSC comments.

The first column of the table is the ratio of the deployment region radius to the radius of a centralized victim system cell. In most instances this ratio will be one; that is, one cell will cover the complete deployment area and the first row of the table is most significant. The situation for larger deployment regions is given for comparison.

The table shows that an exponent of 2 does not compensate for the factor of 3 (slow hopping) case except in very large, multiple cell areas; that is, cases where the radius ratio exceeds 2 (and the deployment area exceeds 4 times the cell area). It doesn't compensate for the factor of 9 (fast frequency hopping) case even at a deployment radius ratio of 3 (deployment area 9 times the cell area).

If the exponent is 3, then in the most prevalent case, in which the deployment area ratio is 1, a factor of 2.7 is compensated by the power reduction. This nearly compensates for the slow frequency hopping case (interference factor of 3). Thus, if fast frequency hopping were prohibited, an exponent of 3 would be acceptable, providing the Aironet proposal of 100 mw maximum is observed and the power level limit is equal to 100 mw divided by the bandwidth (in MHz) cubed.

In the Notice, HomeRF proposed a maximum power level of 1 watt and an exponent of 1. The IEEE LMSC comments addressed this and showed the inadequacy. This shows that even the higher exponent is insufficient.