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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

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

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

REPLY COMMENTS OF PROXIM, INC.

Proxim, Inc. ("Proxim"), by counsel and pursuant to Sections 1.415 and 1.419 of the Commission's rules, hereby submits Reply Comments in the above referenced proceeding.[1] Proxim is a world leader in wireless local area networking devices and an active participant in this proceeding. These Reply Comments respond to initial comments submitted by several parties and include the technical statement of Dr. Leigh M. Chinitz, the Strategic Initiatives Manager of Proxim ("Technical Statement").

Taken as a whole, however, the comments demonstrate the difficulties facing the Commission when it attempts to make incremental changes in the Part 15 rules for unlicensed radio communications. The rules themselves are uneven in their reach; overly specific in some instances, too ambiguous in others. Over the years, the many manufacturers who offer products under these rules have taken a wide variety of approaches to interpretation of and compliance with the rules. When the Commission then proposes to change the rules, usually in response to advances in the state of the art and concomitant petitions and requests from industry, parties take widely divergent positions, giving the Commission little consistent guidance.

Moreover, the regulatory process itself, with its lack of real time interactivity among the parties and with the Commission staff, as well as the inevitable delays associated with the process, compounds these difficulties. From its inception almost three years ago, this proceeding is, perhaps, the best recent example of the defects in the Part 15 rulemaking process.

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[1] In the Matter of Amendment of Part 15 of the Commission's Rules regarding Spread Spectrum Devices, *Further Notice of Proposed Rule Making and Order*, (released May 11, 2000) [hereinafter "*FNPRM*"].

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List A B C D E

Accordingly, Proxim urges the Commission to step back and convene an industry forum to deal with the issues posed by the Commission's proposals. The Commission staff should take an active role in such a forum, facilitating and leading the discussion among the industry participants.

I. ADAPTIVE FREQUENCY HOPPING RULES SHOULD COEXIST WITH THE PRESENT WIDEBAND FREQUENCY HOPPING RULES.

Proxim reiterates its belief that adaptive hopping rules should coexist with, but not replace, the current wideband frequency hopping rules found in Section 15.247(a)(1)(iii). While supporting the Commission's encouragement of adaptive hopping technologies, Proxim believes that the current proposal, if mandatory, could be interpreted to nullify the existing Section 15.247(a)(1)(iii).

The modified rule proposed by the Commission would allow the use of 15 non-overlapping channels only when a system recognizes the existence of other users and adapts its hopset to avoid hopping in occupied channels. As pointed out in Proxim's initial comments, the Commission's proposed modification could have the unintended effect of rendering Section 15.247(a)(1)(iii) meaningless. A system using 5 MHz channels and 15 non-overlapping channels will occupy nearly the entire available 2.4 GHz band leaving no room for avoiding the use of occupied channels in violation of Section 15.247(a)(1)(iii). Intersil agrees that the Commission should "allow for the operation of WBFH devices as previously addressed in the First Report and Order in this docket and ... allow for the use of adaptive hopping as requested by the Joint Petitioners." Comments of Intersil Corp., ET Docket 99-231, at 3-4 (filed August 27, 2001).

Proxim and Intersil are not alone in their opposition to mandatory adaptive hopping. For example, Apple urges the Commission to "encourage strongly, but not mandate, that technology developers use sound methods to intelligently select hopping frequencies to avoid interference." Comments of Apple Computer, Inc., ET Docket 99-231, at 4 (filed August 27, 2001). Additionally, Texas Instruments and Widcomm agree that adaptive hopping should not be mandatory. *See* Comments of Texas Instruments, ET Docket 99-231, at 3 (filed August 27, 2001) ("adaptive hopping should not be mandatory for FHSS, but should be encouraged"); Comments of Widcomm, ET Docket 99-231, at 2 (filed August 27, 2001) ("we urge the Commission to allow, <u>not</u> require adaptive hopping").

In summary, Proxim is opposed to mandatory adaptive frequency hopping as proposed by the Commission, because it would un-do the wideband frequency hopping permitted in the earlier phase of this proceeding. Accordingly, the Commission should maintain Section 15.247(a)(1)(iii) and create a new rule concerning adaptive hopping. As discussed more fully below, the new rule should mandate adaptive hopping and require use of a minimum of 60% of the band with no power reduction.

II. A BALANCE MUST BE MAINTAINED BETWEEN ALLOWING ADAPTIVE FREQUENCY HOPPING AND MAINTAINING A SPREAD SPECTRUM PHILOSOPHY.

Proxim pointed out in its initial comments that the Commission's choice of 15 channels as the preferred number of overlapping channels required to span 75 MHz of spectrum appears arbitrary and would undermine the sharing philosophy of the spread spectrum rules. A number of parties, however, support the Commission's proposal to allow frequency hopping technologies to use as little as 18% of the available spectrum in the band.[2] Such support is based principally on two arguments. First, the parties contend that, while Section 15.247(h) allows intelligent hopping, the requirement that 75 hops be used effectively bars it, since the 2.4 GHz unlicensed band is only 83.5 MHz wide, only 8.5 MHz of frequency margin is allowed for FHSS systems. Second, they claim that the use of adaptive frequency hopping will lessen the likelihood of interference in the 2.4 GHz band. Proxim disagrees with both contentions.

The Commission's rules do not "effectively bar" intelligent frequency hopping. For hopping systems with bandwidths of 1 MHz or less the only requirement is that 75 hops be used. If a system were to use a hopping bandwidth of 800 kHz, for example, the requirement would be for it to use only 60 MHz of spectrum leaving 23.5 MHz for frequency avoidance hopping. Even for hopping systems of 1 MHz or more, intelligent hopping can mean more than simple frequency avoidance, as demonstrated by the HomeRF protocol. This protocol ensures that, for a static interferer up to 31 MHz in width, no two consecutive hops will be within the interference band. This is a very effective method for maintaining low-latency transmission in the presence of in-band interference.

Moreover, while frequency hopping systems will occasionally collide with other users of the spectrum, the parties who assert that "[t]he result of this inefficient process is a reduced data rate for affected systems and longer frequency occupancy than otherwise would be necessary," *Apple* at 4, ignore the fact that the use of adaptive frequency hopping will not always lessen interference. The examples given by Apple and other parties are focused mainly on a single, very specific, scenario. That scenario is the one in which an 802.11b network (22 MHz frequency static signals) is in the same vicinity as a Bluetooth network (1 MHz frequency hopping signals). Interference is reduced, this argument goes, because the Bluetooth transmitters can choose a hopset that avoids the part of the band occupied by the 802.11b transmitters and receivers.[3]

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[2] 15 MHz is 18% of the available 83.5 MHz.

[3] *See, e.g., Intersil* at 2 ("[t]he Commission's proposal allows the two technologies to peacefully coexist when operating in close proximity of each other and has been shown to be very effective in improving the throughput of both types of devices"); Comments of IEEE 802, ET Docket 99-231, at 5 (filed August 27, 2001) ("[t]he intent of IEEE 802 is to enable 'low power, narrowband FH devices,' such as Bluetooth, to elect to reduce their number of hopping channels from the current minimum of 75 hopping frequencies to some reduced hopset of <75 by employing intelligent, adaptive hopping algorithms to significantly

Thus, in this instance, frequency hopping over fewer channels may help reduce intersystem interference. The Bluetooth-802.11b hypothetical, however, is but one interference situation that will arise in the 2.4 GHz band. In countless other scenarios, *wider* spreading is the key to lower intersystem interference. As shown in the Technical Statement, the use of spreading plays a very important role in an unlicensed frequency band envisioned for multiple, uncoordinated radio systems. The Commission's proposal for adaptive hopping would allow frequency hopping systems to use as little as 18% of the band. With only 18% of the band used, the interference probability for any given system with 20 other nearby systems in operation, all using the same narrow bandwidth, is as high as 75%. *See Technical Statement* at 2.

Proxim reiterates its recommendation that frequency hopping systems in the 2.4 GHz band be required to make use of a minimum of 60% of the available spectrum in the band. The 60% threshold would serve the needs of many manufacturers, while preserving the underlying sharing philosophy of the Part 15 rules.

First, regarding the Bluetooth-on-802.11b interference scenario discussed by several parties, a Bluetooth system needs, mainly, to avoid a 22 MHz bandwidth 802.11b system. Therefore, 61.5 MHz, or 74% of the total band, should be available for use.[4] Second, the rules for the 5.725-5.850 GHz band, (125 MHz of spectrum) permit 1 MHz frequency hopping systems to use as few as 75 hopping channels. This is 60% of the available bandwidth.

Finally, the requirement that frequency hopping systems use at least 60% of the band will prevent those hopping systems from avoiding each other completely and, therefore, filling up the band. Even if these systems were to use the same spectrum, the interference probability with as many as 20 co-located systems would be as low as 33%. *See id.*

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improve their ability to coexist with IEEE 802.11b/g, IEEE 802.15.3, IEEE 802.15.4, and other "static, wideband" systems, as well as eliminating problems with interference from microwave ovens"); Comments of Agere Systems, ET Docket 99-231 at ¶6 (filed August 24, 2001) ("the current requirement for FHSS systems with bandwidths of 1 MHz or less to employ at least 75 non-overlapping hopping channels makes it impossible for FHSS systems such as Bluetooth to avoid hopping on frequencies which are occupied by wider bandwidth DSSS systems such as IEEE 802.11b systems which share the band").

[4] Even rules that allowed Bluetooth systems to avoid two simultaneous 802.11b systems would still leave 39.5 MHz, or 47% of the total band, for hopping. Proxim does not support, however, the idea of crafting rules designed to allow one technology to stake out half of the band while allowing another technology to stake out the other half. Such a notion runs counter to the basic philosophy of the Commission rules that are intended to accommodate uncoordinated systems.

III. ADAPTIVE FREQUENCY HOPPING SYSTEMS SHOULD BE ALLOWED THE SAME POWER AS NON-ADAPTIVE SYSTEMS.

In its Comments, Proxim proposed that adaptive frequency hopping systems be allowed to operate at the same power as non-adaptive systems, since many devices for which adaptive frequency hopping would be useful, such as cordless telephones, would not be able to operate at the 9 dB power reduction proposed by the Commission. While adaptive hopping may be useful in improving the quality of a cordless phone connection, the range achieved by a lower power, 125 mW transmitter might not be sufficient for the phone application. A reduction in the transmit power by 9 dB is nearly equivalent to a loss in range of a factor of 3, in the case of free space propagation. *See id.* at 3.

Several parties suggest that the Commission need not require hopsets be adapted so long as power reduction is required. *See, e.g., Apple* at 4; *Texas Instruments* at 3; Comments of the Wireless Communications Association International, Inc., ET Docket 99-231, at 1 (filed August 27, 2001). Another suggests that "either adaptive hopping or the 125 mW power limit is adequate to compensate for any increased risk of interference from a 15-74 hop system." Joint Comments of 3Com Corp., Clearwire Technologies, Inc., InterWAVE Communications Inc., LinCom Wireless, Inc., Symbol Technologies, Inc., Vocollect, Inc., ET Docket 99-231 at 7 (filed August 27, 2001) [hereinafter "*Joint Commenters*"].

If, as many parties point out, power reduction and mandatory adaptation are redundant, Proxim urges the Commission to permit reduced hopsets together with mandatory hopset adaptation, while leaving the maximum permitted power unchanged. This will make hopset adaptation a useful tool for frequency hopping devices serving the whole range of applications now served by those devices. Additionally, this will make it more likely that a wide range of devices will make use of the adaptive frequency hopping rules and, thus, offer protection to those technologies in the 2.4 GHz band that are more susceptible to in-band interference, like the IEEE 802.11b systems. *See Technical Statement* at 2-4.

IV. DIGITAL TRANSMISSION TECHNOLOGIES SHOULD BE ALLOWED THE SAME POWER AS DIRECT SEQUENCE SPREAD SPECTRUM TECHNOLOGIES.

As stated in Proxim's initial comments, devices certified as digital transmission devices should be permitted the same maximum output power as those certified using direct sequence spread spectrum rules. Proxim's position finds wide support among various parties. For example, Western Multiplex states that "[t]ransmitters that demonstrate peak power densities equivalent to current spread spectrum regulations, but without demonstration of processing gain, should be allowed to operate under the same conditions as those that demonstrate processing gain." Western Multiplex, ET Docket 99-231, at 1-2 (filed August 27, 2001).

Similarly, Texas Instruments supports "the same maximum 1 Watt output power limit that now applies to Direct Sequence Spread Spectrum (DSSS) devices." *Texas Instruments* at 7. Additionally, the Joint Commenters state that "[a] victim receiver is affected primarily by the amount of incoming RF energy, and much less (if at all) by the specific form of modulation. Accordingly, the Commission can safely authorize digital modulation systems at a full watt of output power, under the same antenna-gain rules as spread spectrum systems, with no significant increase of interference to other users." *Joint Commenters* at 4.

Despite this widely held view, some parties, such as Agere, urge that "[t]he 1 Watt limit proposed in the *Further Notice* is unnecessarily high for ADTs and a maximum power of 125 mW is recommended." *Agere* at Appendix A. Essentially, Agere argues that if a given coverage area can be achieved using a lower power, there is no good reason to use a higher power and that the use of a higher power will cause unnecessary interference levels. While undoubtedly true, this argument is somewhat beside the point. The coverage area for a wireless LAN system will be based on the coverage needs of the user (*i.e.*, school, hospital, business, etc.) who is deploying it. The lower the power of the individual transmitters, the lower their effective range and the more transmitters will be necessary to cover the same area. The problem with an increased number of transmitters is, as Agere states, that "more devices means more interference potential." *Id.* at 20.

For example, if eight lower-power access points are needed to replace one high power point, the median of the distribution rises over 3 dB. This rise means that the level of the interference is twice as high in the case of eight access points, even though each of the access points is at a lower power. *See Technical Statement* at 8. Thus, while system designers always have the option and the incentive to use a lower power to cover an area if that lower power is sufficient, the only result that arises from a mandatory lowering of the output power for digital transmission devices is to require more devices in areas where fewer, at higher power, could suffice. As demonstrated in the Technical Statement, the result of this scenario is more interference, not less. *See id.*

V. THE COMMISSION'S PROPOSED POWER SPECTRUM DENSITY LIMITS ARE ADEQUATE FOR DIGITAL TRANSMISSION TECHNOLOGIES.

Several parties oppose the Commission's proposed power spectral density limits of 8 dBm/3 kHz for digital transmission systems. The IEEE 802.11 Committee asserts that "the proposed digital transmission systems could heavily interfere with all currently deployed direct sequence spread spectrum systems," and suggests that a new requirement in dBm/MHz be added to the rules. *IEEE 802.11* at 6. Various parties propose alternative spectral density limits. For example, Agere believes "a maximum power spectral density limit of no greater than 10 dBm/MHz is a reasonable limit." *Agere* at ¶23. Meanwhile, Intersil proposes the adoption of the UNII band, 5.250-5.350

GHz rules, including the 11 dBm/MHz peak power spectral density rule, for use in the 2.4 GHz band. *See Intersil* at 5.

None of these parties, however, presents any analysis to substantiate either their calls for additional power spectral density limits or their claims of heavy interference if such a limit is not imposed. In fact, in previous filings in this proceeding, some of these same parties appeared to argue precisely the opposite point.

Intersil, for example, now appears "concerned" that the flexibility of the Commission's 1 watt peak power limit and spectral density requirement of 8 dBm/3 kHz "could also lead to proliferation of inefficient transceivers operating at very high power levels." *See Intersil* at 6. Yet, Intersil opposed the initial rule change to permit the use of a lower power spectral density technology.

In that earlier proceeding, the Commission sought to change the original frequency hopping rules, which permitted the use of 1000 mW in a 1 MHz channel (30 dBm/MHz, or 4.8 dBm/3 kHz), to allow the use of 200 mW in a 5 MHz channel (16 dBm/MHz, or -9.2 dBm/3 kHz.) *See* Amendment of Part 15 of the Commission's Rules regarding Spread Spectrum Devices, *Notice of Proposed Rulemaking*, ET Docket 99-231, 14 FCC Rcd 13046 (1999). In that proceeding, Intersil argued that "due to the emphasis of frequencies offset from the center frequency, interference spectra with a flat shape are more detrimental than interference spectra with a peaked shape having the same overall power." *See* Comments of Intersil, letter from Larry Ciaccia, FC 99-231 at 1 (filed September 29, 1999).[5] At no point was Intersil concerned with the fact that the interferer is hopping. Rather, its analysis focused entirely on the convolution of the interfering WBFH spectral shape with the victim Bluetooth spectral shape.

It should not be considered self-evident, therefore, that signals with lower spectral densities cause less interference than signals with higher spectral densities. Unless analysis is submitted which shows otherwise, the Commission should retain the 8 dBm/3 kHz power spectral density limit that has worked effectively to avoid harmful interference in the 2.4 GHz band to date.

VI. ADAPTIVE FREQUENCY HOPPING RULES SHOULD NOT BE SUBJECT TO AN INTERIM WAIVER.

Several parties stated that, in the same way that the Commission has provided an interim waiver for digital transmission systems, they should provide a similar waiver for systems that want to employ adaptive frequency hopping. *See IEEE 802.11* at 5; *Intel*

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[5] Intersil points out that their "paper was written to examine the impact of WBFH on Bluetooth, but the results are applicable to any conventional FHSS system which operates in compliance with the Commission's Rules as currently written." Comments of Intersil, technical paper entitled, *Effects of WBFH Interference on Bluetooth Receiver Reliability*, ET Docket 99-231, at 1 (filed September 29, 1999).

at 2; *Apple* at 11. Proxim is opposed to this suggestion.

The purpose of the rulemaking process is to allow all interested parties to offer input regarding a proposed change to the Commission's rules. Especially in the case of the unlicensed spectrum rules, the rulemaking process is used to ensure, as much as possible, that any rule change will not lead to unacceptable interference. The adaptive frequency hopping proposal in the *FNPRM* is just that – a proposal. No waiver to operate under that proposal should be granted until it has been vetted by the interested parties: That the Commission granted such a waiver for the digital transmission devices is of no moment.

Many of the parties who have proposed such a waiver should be among the first to agree that neither waiver is a particularly good idea. In its *FNPRM*, the Commission granted a waiver for the authorization of digital transmission devices because of its determination "that authorization of Wi-LAN's device and other digital modulation systems prior to our adoption of final rules will not result harm to other radio operations." *FNPRM* at 26. Despite the Commission's confidence, the IEEE 802.11 Committee states that "the Commission needs to include an additional rule to prevent the new digital transmission systems from causing unacceptable levels of interference." *IEEE 802.11* at 5-6. Additionally, Apple states that "[u]nder the Commission's proposal DTS devices ... could occupy a 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." *Apple* at 8-9.

These comments, and many others calling for changes to the Commission's proposal for digital modulation systems, are proof that short-circuiting the FCC's process is not advisable, because, no matter how well meaning the objective, it is not possible for a single entity to foresee all of the ramifications of a potential change in the rules.

CONCLUSION

While supporting continued efforts to permit flexible use of the 2.4 GHz band by permitting a variety of modulation techniques, Proxim urges the Commission to step back and convene an industry forum to deal with the issues posed by the Commission's proposals and urges the Commission staff to take an active role in facilitating and leading the discussion among the industry participants.

Finally, with or without an industry forum, the Commission should not obviate its recently adopted wideband frequency hopping rules or restrict power levels for devices that use adaptive hopping techniques or digital transmission.

Respectfully submitted,

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September 25, 2001

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STATEMENT OF
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(ET DOCKET 99-231)

I. Wider Spreading Typically Leads to Lessened Interference

The Bluetooth™-on-802.11b interference scenario discussed by several parties is one in which frequency hopping over fewer channels may help reduce intersystem interference. As demonstrated below, wider spreading generally leads to lower intersystem interference.

The construction of the 2.4 GHz band rules, and the use of spread spectrum devices for that band, is based on the idea that systems will be completely *uncoordinated.* There has been, up to now, no spectrum etiquette defined for this band, and statistics then dictate that the more spectrum over which the transmission is spread, the lower the probability of interference between systems. For example, looking only at 1 MHz frequency hopping systems with completely random hopping patterns, the statistics show that the odds of a system *not* being on a given channel, where N is the total number of channels used, is

$$P_{not} = N - 1/N.$$

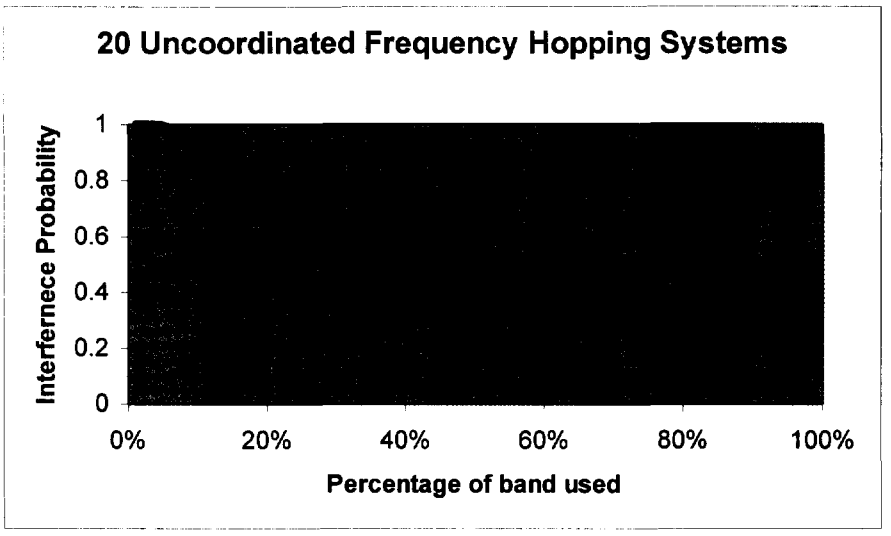
Therefore, with M uncoordinated systems, the probability of having none of those systems on a specific channel is

$$P_{M,not} = \left(N - 1/N\right)^M$$

The interference probability (where interference is defined as having any other frequency hopping system being co-channel to the target system), then, for any given system (occupying only a single channel at a single time) is

$$P_{\text{int}} = 1 - \left(N - 1/N\right)^M$$

For 20 co-located systems (M=20) the result of this interference calculation is shown below:



As shown by this figure, the use of spreading plays a very important role in a band envisioned for multiple, uncoordinated systems. The current FCC proposal for adaptive hopping would allow frequency hoppers to use as little as 18% of the band. With only 18% of the band used, the interference probability for any given system with 20 other nearby systems in operation, all using the same narrow bandwidth, is as high as 75%.

II. Current Power Levels For Adaptive Frequency Hopping Systems Should Be Retained

Proxim is opposed to mandatory adaptive frequency hopping as proposed by the Commission, because it would un-do the wideband frequency hopping permitted in the earlier phase of this proceeding. Proxim, however, supports mandatory adaptive hopping under rules that requires use of a minimum of 60% of the band with no power reduction. If the Commission permits reduced hopsets together with mandatory hopset adaptation, while leaving the maximum permitted power unchanged, hopset adaption will become a useful tool for frequency hopping devices serving the whole range of applications now served by those devices.

Viewed another way, this will make it more likely that a wide range of devices will make use of the adaptive frequency hopping rules and, thus, offer protection to those technologies in the 2.4 GHz band that are more susceptible to in-band interference, like the IEEE 802.11b systems. If, for example, a cordless phone detects an interfering signal, but also determines that by adapting its hopset to avoid the interference and dropping its power by 9 dB it will lose its existing link, it will choose to remain un-adapted and continue to interfere with, and be interfered by, the in-band signal.

The effect of these users choosing not to adapt their hopsets can be estimated in the following way. Free space path loss between two isotropic antennas can be expressed as

$$PL[dB] = 20\log f[MHz] + 20\log d[km] + 32.45$$

where PL is the path loss, f is the frequency, and d is the distance between the antennas. If the transmit power is reduced by 9 dB, the link margin must be compensated with a reduction in the path loss by 9 dB. Therefore,

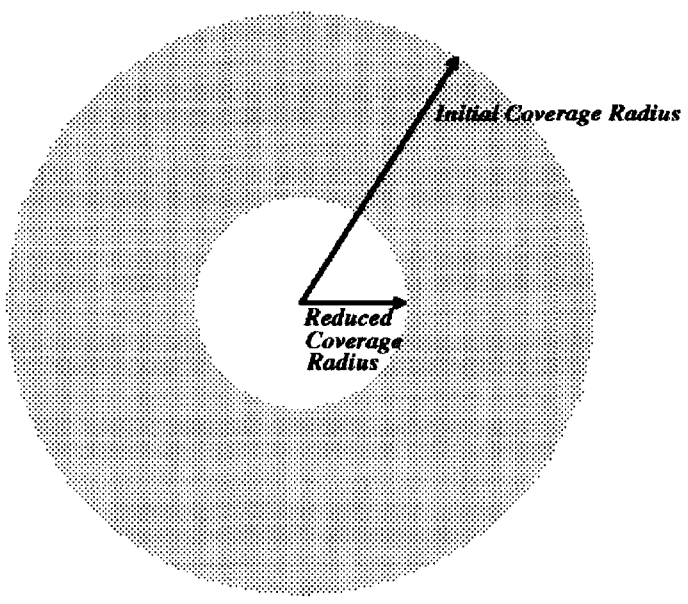
$$PL_1[dB] = 20\log f[MHz] + 20\log d_1[km] + 32.45$$

$$PL_2[dB] = PL_1[dB] - 9dB = 20\log f[MHz] + 20\log d_2[km] + 32.45$$

These expressions can be combined to find the ratio of the distances.

$$\frac{d_1}{d_2} = 10^{9/20} = 2.8$$

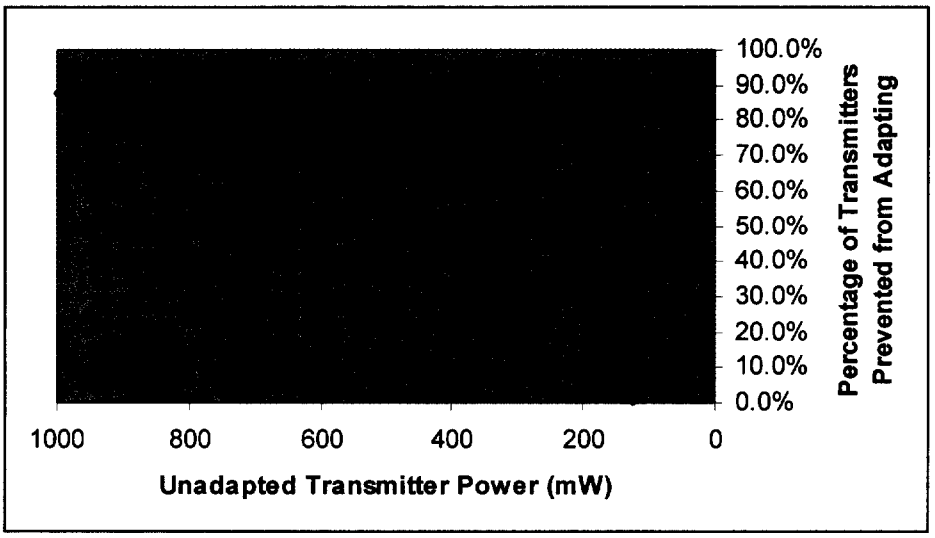
Thus, a reduction in the transmit power by 9 dB will result in a reduction in the effective range by a factor of 2.8. This is shown in the following figure:



All of the devices in the shaded area will choose not to adapt their hopsets rather than lose their links. With a uniform distribution of devices, the ratio of the areas describes the ratio of devices that will choose to use the hopset adaption mechanism.

$$\frac{2.8^2 - 1^2}{1^2} = 6.8$$

Therefore, all of the devices in 6.8/7.8, or 87% of the area, will choose to continue with an unadapted hopset rather than adapt their hopsets. While this analysis is for the worst case, in which the unadapted transmitter uses the maximum possible output power (1000 mW in this band), the following figure shows the results for a range of output powers.



As this figure shows, for the majority of output powers allowed under the rules, more than half of the deployed units will choose not to use hopset adaptation if power reduction in required. Even for unadapted output powers as low as 250 mW, 50% of the units will choose not to adapt their hopsets because it will mean losing their connection with the base station.

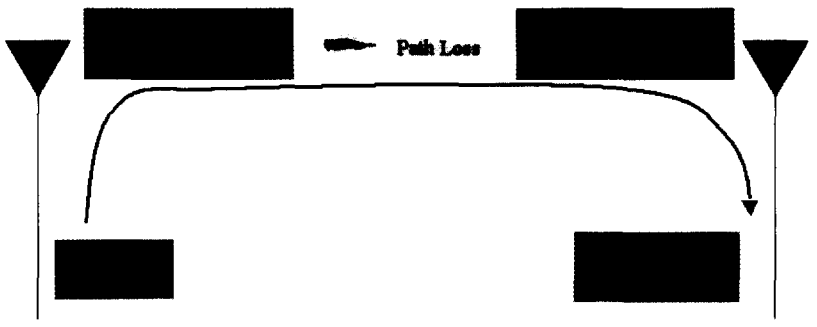
Allowing devices with an adapted hopset to operate at the same output power as those with an un-adapted hopset will make hopset adaptation a more useful interference avoidance mechanism.

III. Digital Transmission Technologies Should Be Allowed the Same Power as Direct Sequence Spread Spectrum Technologies

In their Appendix A, Agere Systems provides a technical analysis intended to support their call for reduced power for ADTs. *See* Comments of Agere Systems, ET Docket 99-231 (filed August 24, 2001). In its analysis, Agere examines three different system topologies, the omni/WLAN systems, the point-point systems, and two classes of point-multipoint systems.

The analyses for all of these cases consist of link budgets. Agere describes the intended application for the different topologies, and then shows that a certain type of link budget is sufficient to enable that application. The link budgets, stripped to their essentials, can be represented by the following figure:

Simple Link Budget Diagram



$$Path\ Loss_{(Free\ Space)}\ [dB] = 20\log f[MHz] + 20\log D[km] + 32.45$$

The transmitted power (P_T) plus the gain of the transmitting (G_T) and receiving antennas (G_R) minus the path loss (PL) is equal to the signal received at the output of the receiving antenna (Pout).

$$P_T + G_T - PL + G_R = Pout$$

In each of their analyses, Agere assumes free space path loss, described by the expression

$$PL(dB) = 20\log f(MHz) + 20\log D(km) + 32.45$$

for antenna gains expressed relative to isotropic antennas.

In their analysis of the omni/WLAN case, Agere presents three link budgets which are summarized in the following table.

Case	P_T (dBm)	G_T (dBi)	G_R (dBi)	Pout (dBm)	Resulting PL (dB)	Equivalent D (km)
1	30	6	6	-58.3	100.3	1.008
2	18	0	6	-58.2	82.2	0.125
3	18	6	0	-58.2	82.2	0.125

Based on the statement that "the 'Omni/WLAN' usage case applies to systems that are intended to cover relatively limited areas with a more or less cellular structure having a cell radius on the order of tens to perhaps, at most, a couple of hundred of meters," Agere uses the above results to argue that the use of the higher power, "is inconsistent with the cellular reuse goals of typical WLAN systems and would result in inefficient use of the spectrum an unnecessarily high potential for interference to other systems in the surrounding area." *Id.* at 15, 18. On the other hand, they claim that the use of the

lower power options "will result in far lower potential for interference to other systems in the surrounding area." *Id.* at 19.

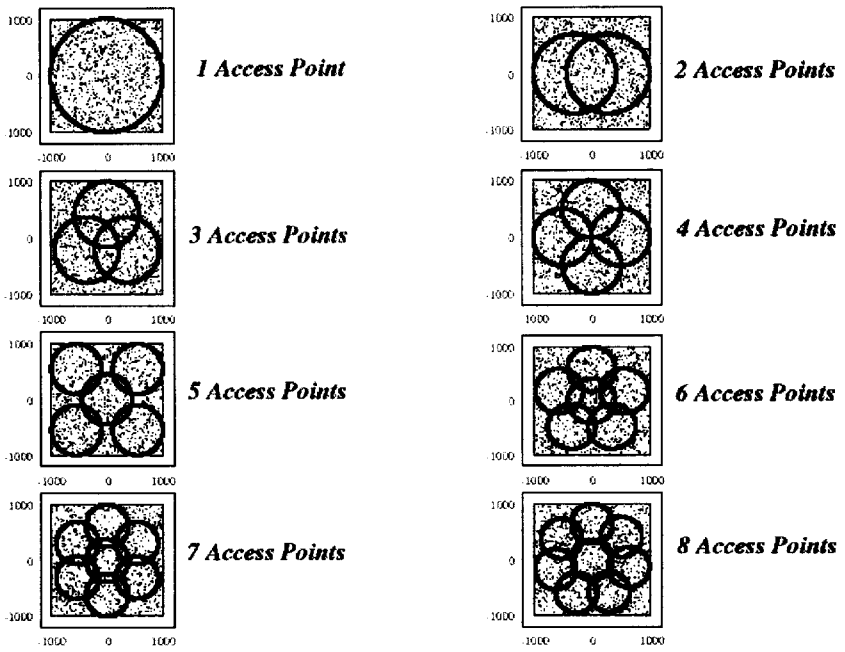
In other words, this analysis says that if asystem is intended to cover only 125 meters, it is best to use a transmit power commensurate with that goal. While this is true, this is a very incomplete analysis of the true interference situation.

In reality, an Omni/WLAN deployment will be intended to cover a specific coverage area. The question that should be asked is, what method of covering that area causes the least interference to other users, fewer access points using higher powers, or more access points using lower powers. This question is analyzed below.

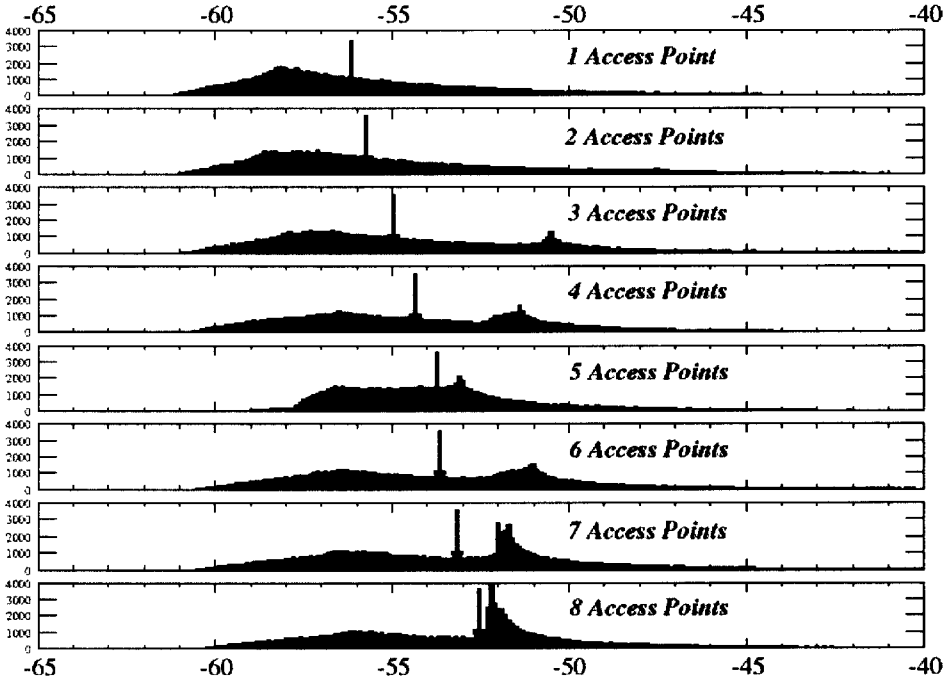
For convenience, the same link budget parameters that Agere used in their examples is assumed. Additionally, like Agere, a free space propagation model is used. In Case 1, above, the radius of coverage for a single access point is 1008 meters. Therefore, the resulting interference with different numbers of access points required to cover this same area of about 3.2 million square meters is examined.

Because of the use of free space propagation (a square law propagation model) it is straightforward to calculate the number of additional access points that will be needed to cover the same area as the transmit power of the access points is reduced. Since the transmit power is proportional to the square of the coverage radius, the number of required access points will rise linearly as the allowed transmit power falls.

The following figure shows a set of topologies used to cover the same area using access points of different powers. The small dots on each figure show a small sampling of points used to measure the signal level that a receiver would measure. For a receiver that is not part of this system, this signal level would be perceived as interference.



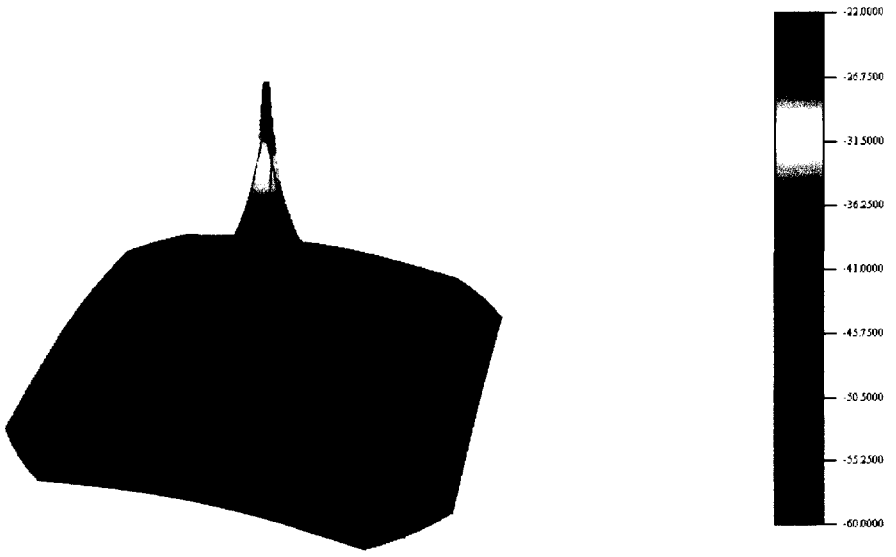
The signal level was measured at 100,000 points within this square of 1008 meters on each side. The distribution of this signal level is shown in the following figure, for each of the topologies above.



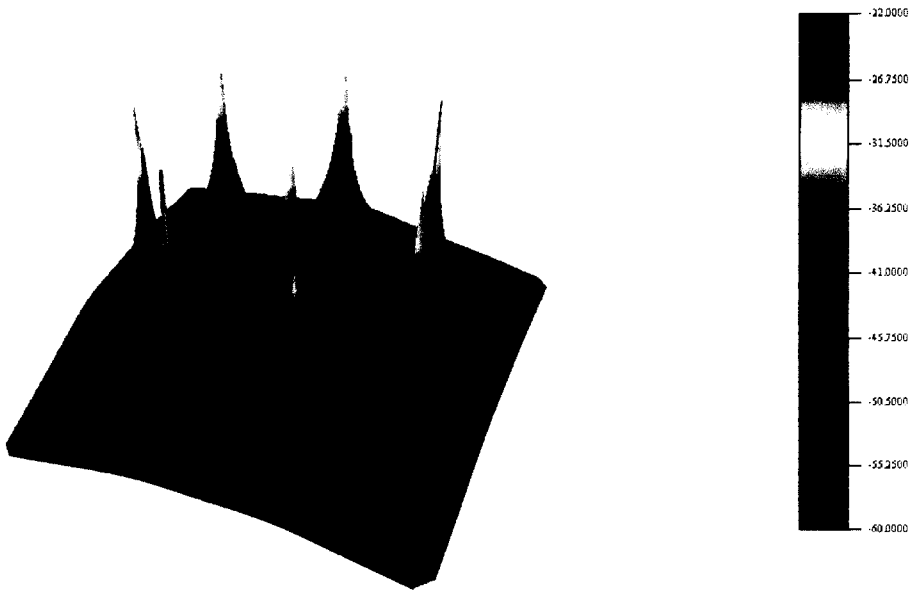
Distribution of Received Signal (dBm)

The arrow in each of these distributions shows the location of the median of the distribution. The trend shown by the distributions is very clear. *As the allowed power is reduced so that the number of required access points increases, the average interference level rises*. That is, it does not help the interference situation to lower the allowed power of the devices; it actually makes the interference worse. The median of the distribution rises over 3 dB as the number of required access points rises from 1 to 8. A rise of 3 dB means that the level of the interference is twice as high in the case of 8 access points, even though each of the access points is at a lower power.

The reason that this happens is clear from an examination of the energy distribution in the two most extreme cases. The following plot shows the energy distribution for a single 1000 mW access point.

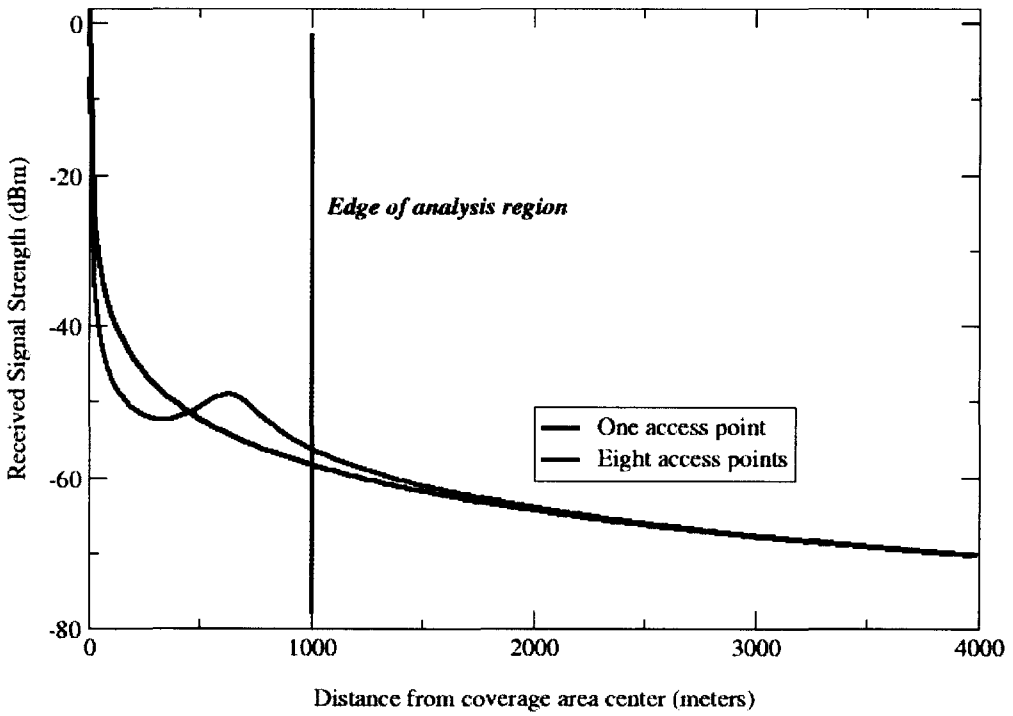


Most of the energy is concentrated in the center of the coverage area, near the access point. The following figure shows the energy distribution for 8 access points, at 125 mW each, used to cover the same area.



Even though the power around each access point is not as high, there is a higher probability that a receiver will be close to one of these access points, and this results in the higher probability of interference.

One final point is that it is irrelevant to users outside of this immediate region which power level is used. That is, for users far away, eight access points at 125 mW look equivalent to a single access point at 1000 mW. This is shown in the following figure.



Respectfully submitted,

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