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

ORIGINAL

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

REPLY COMMENTS OF THE COMMITTEE FOR UNLICENSED BROADBAND ENABLEMENT ("CUBE")

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SUMMARY

Intel, Micrilor, Motorola, Proxim, and Siemens have joined together as the Committee for Unlicensed Broadband Enablement ("CUBE") to urge the Commission quickly to adopt its proposal to permit 2.4 GHz frequency hopping spread spectrum ("FHSS") devices to use bandwidths up to 5 MHz. The CUBE companies - all of whom are active, major participants in the 2.4 GHz spread spectrum market, all of whom manufacture both FH and direct sequence ("DS") devices, and all of whom remain committed to their 1 MHz FH product lines - have analyzed in detail the technical and market issues associated with the introduction of wideband frequency hopping ("WBFH") technologies. In each case, they have concluded that WBFH technologies will provide enormous benefits to end users and should be authorized.

As the comments filed in this proceeding demonstrate, there is strong and broad-based support for adoption of the Commission's WBFH proposal. Manufacturers, component suppliers, end users, software developers, systems support experts, and others agree that the authorization of WBFH will benefit users in education, health care, business, residential, and other environments, as well as persons with disabilities, without impeding the fair use of the 2.4 GHz band by other devices.

Most importantly, WBFH will enable affordable high-speed wireless communications in the home. The true power of broadband *to* the home will be realized only when residential users are able to distribute broadband data *throughout* the home. As a result, the Commission's WBFH proposal is an integral part of its broader broadband effort.

WBFH also will have other benefits. It will promote efficient spectrum use; retain the low-power consumption benefits of FH technologies; provide a smooth upgrade path for existing 1 MHz FH systems; and otherwise promote the use of wireless technologies to meet the needs of bandwidth-hungry users.

Moreover, adoption of the Commission's WBFH proposal will restore regulatory parity to the two types of spread spectrum technologies: direct sequence and frequency hopping. As a result, it will free developers and users to employ whichever technology is best suited to meet their needs and will permit the marketplace, rather than regulation, to determine the relative success of these competing technologies.

WBFH will achieve all of these benefits *without* increasing interference levels in the 2.4 GHz band.

The Commission should not be dissuaded by the attacks some have made on WBFH. Claims that WBFH devices will be unable to share spectrum with other users of the 2.4 GHz band and that they will not be able to achieve their performance objectives are motivated by financial self-interest rather than by legitimate technical or other considerations. As the extensive technical analysis in these reply comments demonstrates, WBFH devices will not increase - and, in many cases, actually will decrease - interference levels as compared to currently-authorized 2.4 GHz communications devices.

Moreover, the Commission should not be lulled into believing that any other wired or wireless technology can achieve the benefits of WBFH. No existing wired or wireless technology - including existing FH and DS systems, as well as other unlicensed systems - can provide the bandwidth, price, and performance capabilities that WBFH offers.

For all of these reasons, the Commission should act quickly to adopt its WBFH proposal. Delay will undermine the Commission's broadband objectives and deny residential and other users desperately needed bandwidth for home applications of broadband communications.

TABLE OF CONTENTS

BACKGROUND AND STATEMENT OF INTEREST 2

I. WBFH SYSTEMS WILL PROMOTE THE UBIQUITOUS, TIMELY DEPLOYMENT OF BROADBAND TECHNOLOGIES IN THE HOME 9

A. *The Authorization Of WBFH Systems Will Revolutionize Communications In The Home* 9

1. The Power Of Broadband To The Home Will Be Realized Fully Only When Wireless Broadband Is Available Throughout The Home. 9

2. Frequency Hopping Is The Right Choice For The Convergence Of Voice And Data In The Home. 10

3. WBFH Will Enable Exciting New Applications For Broadband In The Home. 11

4. WBFH Supports The Commission's Initiative Of Enabling Americans With Disabilities To Realize Their Full Potential..... 12

B. *The Benefits Offered By WBFH Devices Can Be Realized Only If The Commission Amends Its Rules* 12

1. WBFH Systems Offer Benefits To Consumers That Cannot Be Matched By High-Rate Direct Sequence Devices 12

2. Frequency Hopping Devices Operating Under the Existing Rules Cannot Provide The Capabilities Of WBFH 13

3. Other Licensed And Unlicensed Alternatives Do Not Provide A Reasonable Alternative to WBFH 13

C. *WBFH Devices Will Save Consumers Billions Of Dollars* 14

II. TECHNICAL CONSTRAINTS WILL NOT IMPEDE WBFH PERFORMANCE ... 15

A. *Multipath Delay Spread Effects Will Not Limit Performance* 17

B. *Partially Overlapped Channels Will Not Limit Performance in the Home* 18

C. *WBFH Systems Will Be Able To Tolerate Any Interference Likely To Be Present In The Home*.....19

III. SUPPORT FOR THE COMMISSION'S PROPOSAL IS WIDESPREAD AND BROADLY REPRESENTATIVE OF THE WIRELESS INDUSTRY AND THE USER COMMUNITY.....23

A. *Bluetooth Does Not Oppose WBFH*.....23

B. *The WECA And WLANA Oppositions Reflect These Groups' Interest In Maintaining An Unfair Advantage For High-Rate Direct Sequence Systems*.....24

C. *The IEEE 802.11 Comments Do Not Reflect The Consensus View Of The IEEE*.....24

IV. WBFH SYSTEMS WILL NOT INCREASE - AND IN MANY CASES ACTUALLY WILL DECREASE - THE INTERFERENCE EXPERIENCED BY OTHER USERS OF THE 2.4 GHZ BAND.....26

A. *WBFH Interference Generally Will Be Much Lower Than The Interference Allowed Under The Existing Rules For FH And DS Systems*.....26

B. *Existing FH And DS Systems Use Maximum Power Limits That Greatly Exceed The Proposed Allowance For WBFH*.....29

C. *Hopping Rate is a Neutral Issue*.....30

D. *Clear Channel Assessment Is Not a Relevant Issue*.....32

E. *WBFH Systems Will Reduce Interference To Existing FH Systems When Compared To Existing 2.4 GHz FH Or DS Interferers*.....33

1. The Opponents' Analysis Of Interference From WBFH To Existing FH Systems Is Flawed.....33

2. The Opposing Parties Did Not Choose Realistic Baselines To Compare WBFH Interference Effects On Existing FH Systems...33

3. Measurements Show That WBFH Reduces Interference.....35

F. *WBFH Systems Reduce Interference To Legacy DS Systems Compared With Existing 2.4 GHz FH Or DS Interferers*.....38

1. The Opponents' Analysis Of Interference For Legacy DS Is Flawed.....38

2. **Measurements, and Even the IEEE 802.11's Own Analysis, Show That WBFH Reduces Interference.** 39

G. *Opponents Of The Commission's Proposal Misstate the Facts In Their Opposition To Overlapping Channels* 40

V. WBFH SYSTEMS ARE IN THE PUBLIC INTEREST 42

A. *Proposed WBFH Rules Make Backwards Compatibility With Existing Systems Straightforward* 42

B. *Logical Back-off Modes For WBFH Improve Spectrum Sharing Etiquette Compared To Direct Sequence Alternatives* 43

C. *WBFH Systems Improve Overall Spectrum Efficiency As Compared To Direct Sequence Alternatives* 43

D. *Adoption Of The Commission's Proposal Would Improve Worldwide Harmonization Of FH Rules* 44

CONCLUSION 45

APPENDICES

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The Committee for Unlicensed Broadband Enablement ("CUBE") is an *ad hoc* group of companies who, with the exception of Micrilor, are members of the HomeRF Working Group companies and, like the HomeRF group, are committed to advancing the state-of-the-art of spread spectrum radio technologies. The individual CUBE companies filed initial comments in this proceeding and formed CUBE in order to discuss with a common voice the comments filed in response to the above-referenced Notice of Proposed Rulemaking ("NPRM"). CUBE's goal is to ensure that unnecessary regulatory restrictions do not hinder the development of frequency hopping spread spectrum devices ("FH").

CUBE and a substantial number of the parties who commented on the NPRM support the Commission's proposal to permit 2.4 GHz band frequency hopping spread spectrum devices to employ channel bandwidths up to 5 MHz (referred to in these reply comments as wideband frequency hopping ("WBFH")). The parties who filed comments opposing the Commission's proposal are, for the most part, manufacturers of direct sequence spread spectrum systems ("DS"). The DS manufacturers have gained a regulatory advantage over proponents of WBFH, which has been translated into a time-to-market advantage, that they wish to keep indefinitely. Consistent with this objective, they have raised a plethora of technical concerns about WBFH, none of which

represents a valid reason for the Commission to change course on WBFH. CUBE, therefore, urges the Commission promptly to adopt its proposed rule change.

BACKGROUND AND STATEMENT OF INTEREST

CUBE's membership includes:

- **Intel:** Intel is the world's largest manufacturer of microprocessors and supplier of networked PC devices. It is the world market share leader in home networking devices.
- **Micrilor:** Micrilor was the first company in the world to develop a high rate (10 Mb/s or above) direct sequence wireless local area network ("WLAN") system. Micrilor has conducted research in spread spectrum communications intensively for over 15 years.
- **Motorola:** Motorola is the world's largest wireless equipment manufacturer and manufacturer of residential broadband cable modems.
- **Proxim:** Proxim is the world's leading supplier of WLAN devices. Last year, Proxim was responsible for 40% of global WLAN shipments. Its market share of WLANs in the 2.4 GHz band was even higher. Proxim manufactures both frequency hopping and direct sequence products.
- **Siemens:** Siemens Information and Communications Products is the world's largest manufacturer of digital radio networked devices for the home ("DECT" telephones).

CUBE's members are active participants in the 2.4 GHz frequency hopping spread spectrum market. CUBE's members manufacture both FH and DS devices for use in the 2.4 GHz band. Including estimated volumes through next year, DS represents a business interest worth hundreds of millions of dollars for these companies. Moreover, CUBE's members remain committed to their 1 MHz FH product lines and have over one million existing customers who rely on these products.

As a result, while CUBE's members strongly support WBFH, they also are committed to preserving a hospitable sharing environment for all current users of the 2.4 GHz band. CUBE supports regulatory changes *only* if those changes will not lead to increased interference in the band relative to the existing regulations – whether it is

interference from WBFH devices into other WBFH devices, into direct sequence devices, into 1 MHz FH devices, or into other devices using the 2.4 GHz band.

The Commission's proposal to authorize WBFH devices in the 2.4 GHz band meets this test. By permitting FH devices to employ bandwidths of up to 5 MHz, the Commission will provide substantial benefits to consumers without jeopardizing any other user of the 2.4 GHz band. Seventy-seven parties, in addition to CUBE's members, filed comments in this proceeding expressing this view.

SUPPORTERS:

Comments endorsing the Commission's WBFH proposal were filed by 82 parties.[1] Support came not only from manufacturers of FH products, but also from manufacturers of DS products and from:

- Entities who supply components and other products and services to manufacturers of wireless products;[2]
- Entities who supply products and services used in connection with spread spectrum networks;[3]
- Software developers, especially those developing software for use in mobile computing applications and systems;[4]
- End users;[5]
- High-technology investment firms;[6]
- Property developers;[7] and
- Other entities involved in the wireless industry.[8]

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[1] See Appendix 1.
[2] E.g., Comments of Abracon, Cal-Chip Electronics, Capax Technologies, Duel Systems, FCI Electronics, The Professional Shopper, Radiall, STMicroelectronics, TAARCOM.
[3] E.g., Comments of Diablo Research Company, Donovan Consulting Group, Prime Performance Technologies, Productivity Enhancement Products.
[4] E.g., Comments of Cerner, Odyssey Software.
[5] E.g., Comments of A. Helal, University of Florida, School PCs, the University of Oklahoma College of Engineering, Dr. John Zaremba.
[6] E.g., Comments of Smith Investments.
[7] E.g., Comments of HQ Business Centers, Randolph Development.

Together, the commenting parties highlighted the many benefits that WBFH technologies offer for users in education, health care, business, residential, and other environments, as well as to persons with disabilities.[9] In particular, WBFH devices will:

- Enable FH spread spectrum technologies to achieve data rates of 10 Mbps and, thereby, meet end users' needs for high-bandwidth transmissions and remain competitive with other wired and wireless technologies;[10]
- Provide a cost-effective solution for residential and other users seeking high-capacity systems;[11]
- Minimize interference with other 2.4 GHz users and, thereby, promote the efficient use of otherwise cluttered spectrum;[12]
- Achieve high-capacity transmissions while consuming very little power - a critical consideration for mobile devices;[13]
- Provide a smooth upgrade path for the existing installed base of 1 MHz frequency hopping spread spectrum devices;[14] and
- Promote the use of wireless technologies more generally and, thereby,

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[8] See, e.g., Comments of CSA Automated, Donovan Consulting Group, Global Wireless Group, Great American Ventures. Three other entities filed comments that did not explicitly support the NPRM but that were quite consistent with the proposal. Kodak suggested that the Commission move towards the ETSI recommendations, which allow WBFH up to 4 MHz wide at no relative reduction in power. L. Brett Glass expressed concerns about keeping WBFH power a factor of five below that allowed for DS systems in outdoor point-point applications - in fact, the Commission's proposal requires exactly a factor of five reduction in power for WBFH. Finally, Wi-LAN, Inc. proposed that the Commission replace the entire existing FH/DS rules with a simple power spectral density and total power limitation combination, as in the UNII band rules. While WBFH devices probably could conform to Wi-LAN's proposed rules, CUBE is concerned that some existing narrowband FH systems might have a peak power spectral density that exceeds Wi-LAN's proposed levels.

[9] See, e.g., Comments of Campbell Union High School District, A. Helal, University of Florida, School PCs, and the University of Oklahoma College of Engineering (education); Business Engineering, Cerner, Data General - Clinical Computing and Handheld Computer Groups, McKesson HBOC, Medical Manager Health Systems, and Open Computing Platforms (health care); Micro Design Services (business); 2Wire, Cayman Systems, HQ Business Centers, and Randolph Development (residential); Intel (persons with disabilities); Wireless Data Corporation (education, corporate, and health care).

[10] E.g., Comments of Alation Systems, Business Engineering, Cayman Systems, Compaq Computer, Copper Mountain, Donovan Consulting Group, Medical Manager Health Systems, National Data Communication, Wireless LAN Interoperability Forum.

[11] E.g., Comments of Luna Communications, Randolph Development.

[12] E.g., Comments of Ericsson, McKesson HBOC, MICRILOR, Siemens.

[13] E.g., Comments of CASIO Manufacturing, Data General - Handheld Computer Group, ICL (a division of Fujitsu Ltd.), School PCs.

[14] E.g., Comments of Wireless Data Corporation.

promote historic preservation, enhance mobility, and make it possible for end users to avoid problems caused by asbestos.[15]

OPPONENTS:

The 35 parties who filed comments opposing the Commission's WBFH proposal generally fall into the following three camps: [16]

- The largest subset of opponents is comprised of 15 IEEE 802.11b DS equipment manufacturers and their trade associations.[17] Within this group, Intersil filed multiple pleadings alleging dire technical consequences if the Commission adopts its WBFH proposal. It also appears that Intersil supplied the bulk of the material that was endorsed by the IEEE 802.11b committee and forwarded to the Commission.

- A very small number of Bluetooth members, all of whom filed virtually identical letters.[18]

- A collection of various interests who did not specifically oppose WBFH but simply opposed any expanded usage of the 2.4 GHz band by Part 15 devices, including devices compliant with IEEE 802.11b and any other 2.4 GHz wireless standard.[19]

As an initial matter, the Commission should reject outright the arguments of the third group opposing any expansion of Part 15 operations in the 2.4 GHz band, in particular, the introduction of WBFH devices. These parties fear that, if Part 15 users suffer interference from ISM devices, Part 15 users will call for limits on ISM emissions in the band.[20] Not only did they provide no factual support for their claim, their proposed solution - restricting Part 15 access to the 2.4 GHz band - directly contradicts

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[15] See Comments of Business Engineering, Northeast Data, Prime Performance Technologies.
[16] Two companies who build outdoor building-to-building link products also filed comments in opposition. Clearly, however, the HRFWG proposal is not relevant to this application. Moreover, it would seem to CUBE that the link budget disadvantages of wider bandwidth and reduced power would make WBFH an unattractive candidate for this application. One of these companies suggested that the Commission restrict WBFH to indoor use only. CUBE suggests that this can be achieved using the EIRP limitation versus antenna gain methodology already in place for the 2.4 GHz band.
[17] See Appendix 1.
[18] See Appendix 1.
[19] See Appendix 1.
[20] See Comments of AHAM, Amana, Fusion Lighting, IMPI, Sharp.

the Commission's long-standing policy favoring unlicensed use of the radio spectrum for a variety of public interest purposes.[21]

While the arguments made by the first group - the manufacturers of DS systems and their trade associations and supporters - may appear, at first blush, to be based on technical grounds, their real objection is economic, not technical.

In 1997, in an exchange of correspondence with Harris Semiconductor (now called Intersil), the Commission's Office of Engineering and Technology ("OET") accepted the notion that direct sequence systems could be manufactured with data rate to occupied bandwidth ratios much higher than previously assumed.[22] OET confirmed that a DS system can be certified if it passes applicable tests and the manufacturer states that the device has at least 10 dB of processing gain.[23] Yet for FH devices, the longstanding requirement of effectively 18.7 dB of equivalent processing gain remains. Thus, the FCC's interpretation of its DS rules conferred a competitive advantage on DS systems *vis-à-vis* FH systems.

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[21] See, e.g., *Amendment of the Commission's Rules to Provide for Operation of Unlicensed NII Devices in the 5 GHz Frequency Range*, Report and Order, 12 FCC Rcd 1576 ¶¶ 15-18 (1997); *Amendment of Parts 2 and 15 of the Commission's Rules Regarding Spread Spectrum Transmitters*, Report and Order, 12 FCC Rcd 7488 ¶¶ 1, 11 (1997); *Amendment of Parts 2, 15, and 97 of the Commission's Rules to Permit Use of Radio Frequencies Above 40 GHz for New Radio Applications*, First Report and Order and Second Notice of Proposed Rulemaking, 11 FCC Rcd 4481 ¶ 33 (1995); *In the Matter of Allocation of Spectrum Below 5 GHz Transferred from Federal Government Use*, First Report and Order and Second Notice of Proposed Rule Making, 10 FCC Rcd 4769 ¶¶ 32-35 (1995); *Amendment of the Commission's Rules to Establish New Personal Communications Services*, Second Report and Order, 8 FCC Rcd 7700 ¶ 185 (1993). Notably, in its 1997 *Spread Spectrum* Report and Order, the Commission rejected a prior attempt by Fusion Lighting to impose susceptibility standards on spread spectrum systems and to adopt additional regulations warning Part 15 manufacturers and users that in-band interference may occur unless susceptibility standards are applied to their systems. 12 FCC Rcd 7488 at ¶ 13.

The arguments made by the other members of the third group also should be rejected. As to the SBA's Comments, the very large number of small businesses - manufacturers, end users, and others -- who urged the Commission to adopt its WBFH proposal belies any claim that the NPRM's notice to small businesses was inadequate or that the introduction of WBFH devices will harm small businesses. The remaining member of the third group, while not a member of the Bluetooth SIG, raised the same arguments set forth in the Bluetooth form letter. Its concerns, thus, are addressed in these reply comments.

[22] See exchange of e-mail correspondence between OET and Brian Mathews, July 1997.

[23] Id.

In the immediate term, OET's interpretation and the Commission's processing gain rules translated into a "first-to-market" advantage. DS proponents, however, now want the Commission to give them a permanent regulatory "leg up." To this end, they are using scare tactics to dissuade the Commission from making changes to the FH rules that will permit development of a technology that offers more to consumers than is offered by DS.

Specifically, the DS proponents have attacked the two basic premises underlying the Commission's proposal to permit WBFH devices, arguing that WBFH devices will cause increased interference to other users of the 2.4 GHz band[24] and that they will not be able to achieve their projected 10 Mb/s data rates due to the detrimental effects of multipath distortions and their use of overlapping channels.[25] Moreover, they claim, the Commission's proposal to limit the power levels used by WBFH devices will not solve the potential interference problem[26] and DS systems cannot (or should not be required to) compensate for the presence of WBFH devices by increasing their processing gain.[27]

Finally, they contend, the proposed rule change is unnecessary, both because existing unlicensed technologies can achieve the cost/performance characteristics of proposed WBFH devices and because any limitations experienced by FH systems are the result of this technology's inherent deficiencies and not any regulatory benefit that has been conferred on DS devices.[28] Indeed, a small number of commenting parties go so far as to imply that any updating of the Commission's Part 15 regulations is unwise

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[24] See, e.g., Comments of Aironet, Clearwire, Digital Wireless, Glenayre, Harris, IEEE 802.11, Intersil, Home Wireless, Nokia, Nortel, WECA, WLANA.
[25] See, e.g., Comments of Harris, Home Wireless, Intersil, WECA.
[26] See, e.g., Comments of Aironet, Clearwire, Digital Wireless, Glenayre, Home Wireless, IEEE 802.11, Kodak, WECA.
[27] See, e.g., Comments of Glenayre, Lucent, WECA.
[28] See, e.g., Comments of Clearwire, Digital Wireless, Glenayre, Harris, Home Wireless, Kodak, Nortel.

because change creates market confusion, undermines stability, and hinders market acceptance of Part 15 devices.[29]

In addition to DS proponents, a relatively small number of Bluetooth members filed comments opposing the Commission's WBFH proposal. These parties argued that Bluetooth receivers will be susceptible to interference from WBFH transmitters; that WBFH transmitters are less "random" than existing FH transmitters and, therefore, are not in the spirit of Part 15; and that the use of overlapping channels will impede WBFH performance, particularly in dense user environments.[30] Notably, approximately as many Bluetooth members filed comments supporting the proposal as opposing the proposal, and more than 95% of Bluetooth's members remained silent on the question. The Bluetooth Special Interest Group took no official position on this issue.

As CUBE shows in the detailed discussion below, WBFH technologies offer a myriad of benefits to consumers. There is, moreover, no substance whatsoever to the concerns expressed by the opponents. Therefore, there is a paramount public interest in adopting the Commission's proposal as soon as possible.

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[29] See, e.g., Comments of Glenayre, Harris, IEEE 802.11; see also Comments of Kodak (change will undermine international harmonization efforts).

[30] See Comments of Alantro, Clarion, Coginitive, Gemini, GM, Polycom, Repeater Technologies, SILICOMP, Silicon Wave, Solectek, and Sonera.

DISCUSSION

I. WBFH SYSTEMS WILL PROMOTE THE UBIQUITOUS, TIMELY DEPLOYMENT OF BROADBAND TECHNOLOGIES IN THE HOME.

A. THE AUTHORIZATION OF WBFH SYSTEMS WILL REVOLUTIONIZE COMMUNICATIONS IN THE HOME.

1. The Power Of Broadband To The Home Will Be Realized Fully Only When Wireless Broadband Is Available Throughout The Home.

The Commission has made the delivery of broadband Internet voice and data services to American consumers over a variety of transmission media a very high priority. To realize the true potential of broadband to revolutionize communications, information, and entertainment in our homes, broadband must be available in more than one location per home. Thus, it should be an equally high priority for the Commission to fostering a variety of home networking technologies that make broadband available throughout the home.[31]

It is unrealistic to believe that any substantial fraction of the 100 million households in the United States will be completely re-wired for networking broadband services in the next decade. Therefore, technologies that employ wireless communications to network voice and data devices in the home are vital tools for enabling the broadband revolution.

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[31] See, e.g., Comments of Copper Mountain Networks (the Commission's WBFH proposal is an important step in ensuring that broadband access in the local loop is matched by flexible broadband networking within end users' premises); Comments of Cayman Systems (high-speed communications to the home must be matched by high-speed delivery of content throughout the home); Comments of National Data Communication (FHSS products must be able to match speeds offered by Cable Modem and ADSL technologies); Comments of Business Engineering (with 100 Mb transfer rates now the common platform for wired networks, wireless networks must be able to achieve 10 Mb rates in order to remain viable and competitive).

2. Frequency Hopping Is The Right Choice For The Convergence Of Voice And Data In The Home.

Among the candidates for short-range, wireless networking technologies, the unlicensed 2.4 GHz band has several compelling advantages, including the greatest amount of bandwidth available to consumers at an attractive price.

Within the 2.4 GHz band, FH spread spectrum systems are the overwhelming choice for broadband voice and data networks in the home today. The primary disadvantage of the 2.4 GHz band is interference from microwave ovens and from an impending avalanche of new communications devices. FH systems, however, are unique in their ability to overcome this disadvantage because they provide excellent interference immunity. Moreover, they are able to achieve high network density in multi-unit dwellings, low latency for voice transmission, and inherently lower cost than DS alternatives.[32]

The 1-2 Mb/s data rates typical of existing FH systems are a good match to initial broadband data rates of typically 100-500 kb/s, along with a very limited number of voice calls. However, several factors now drive the need for higher data rates in wireless home networking, without giving up the highly desirable qualities of FH. These include much higher broadband data rates to the home of 1-5 Mb/s as well as many separate high quality voice calls delivered over the Internet. In addition, frequent transmission of digital images and streaming audio throughout the home increases the need for higher speeds. WBFH systems are ideally suited for these emerging applications.

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[32] E.g. Comments of Texas Instruments (FH technologies are superior to DS technologies for short range, indoor applications); Comments of A. Helal, University of Florida (FH technologies are superior to DS technologies for dense educational applications); Comments of Donovan Consulting Group (FH technologies have specific benefits, and end users should not be forced to select DS devices simply because FH systems are limited by the existing rules).

3. WBFH Will Enable Exciting New Applications For Broadband In The Home.

If the Commission adopts the NPRM expeditiously, WBFH devices could be widely available by mid-2000, offering an abundance of innovative products. A few examples are set out below:

- The Personal Multimedia Communicator - This is a mobile voice terminal and LCD display tablet that draws content and services from any broadband residential gateway. The device can support simultaneous wireline-quality cordless phone calls with interactive real-time video images ("picturephone") and/or shared viewing of Internet images. The device also can be used for web surfing at broadband speeds, displaying digital photos or accessing personal information from the main Home PC.

- The Family Newspaper - A high quality printer that can be placed wherever convenient in the home to print out a personalized periodical "newspaper" of Internet content at a programmed time (for example, every weekday morning at 7:00 am). Dad's paper might have the front page of the Wall Street Journal, the Sports section from USA Today, and the editorial pages of the New York Times. The kids might prefer articles from Rolling Stone and People.

- The Internet Headset - Every family member could have personalized headsets that they could access their favorite Internet audio broadcast in full CD-quality sound. With WBFH many such devices could operate simultaneously, with bandwidth left for Internet surfing and the transmission of digital images. Furthermore, these headsets could "ring" incoming phone calls routed to the individual wearing the headset.

- The Ultimate Gaming Device - WBFH would make possible multiple sessions of broadband Internet gaming appliances, which could be used on a mobile basis anywhere in the home.

This list could continue indefinitely. The ingenuity of innovative electronics companies is boundless once the underlying cost-effective technologies are in place.

4. WBFH Supports The Commission's Initiative Of Enabling Americans With Disabilities To Realize Their Full Potential.

WBFH systems will open up new possibilities for people with disabilities.[33] Currently, research and standards work is underway to develop a protocol by which users could send and receive information according to their desires and specific needs. This work is taking place in the National Committee for Information Technology Standards - Information Technology Accessibility Study Group ("NCITS ITA").[34]

With a high-bandwidth network, using such a protocol, a user could interact with the network sending and receiving information according to his or her individual needs. The network itself dramatically increases users' capability to control and interact with their environments. Exciting new possibilities become available for the full inclusion of people with disabilities in everyday life and in the workforce.

In June 1999, the executive leadership of the HomeRF Working Group attended the Association of Access Engineering Specialists ("AAES") Workshop to explore these possibilities. The HomeRF representatives held extensive discussions with the leadership of AAES, NCITS, ITA, and other participants. This initiative continues with the goal of assuring that the maximum benefit to the disability community is realized in the implementation of the HomeRF-based network.

B. THE BENEFITS OFFERED BY WBFH DEVICES CAN BE REALIZED ONLY IF THE COMMISSION AMENDS ITS RULES.

1. WBFH Systems Offer Benefits To Consumers That Cannot Be Matched By High-Rate Direct Sequence Devices.

Many of the benefits of WBFH for broadband are associated with the easy mapping of FH protocols to existing high quality digital cordless telephones. Further benefits are the robust interference performance and the high network density support

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[33] See Comments of Intel.

[34] Research is underway at Stanford University, the University of Wisconsin, and George Mason University.

for multi-unit dwellings. On the other hand, high-rate DS systems today generally are developed for office networks running typical office software computer applications or for outdoor point-to-point links. For consumer applications, the cost savings associated with WBFH will enable many novel types of broadband Internet appliances. Furthermore, convergence with telephony is much easier with FH than with high-rate DS because of the superior interference immunity and bounded latency of FH.[35]

2. Frequency Hopping Devices Operating Under the Existing Rules Cannot Provide The Capabilities Of WBFH.

While devices that comply with the existing FH rules can be made very robust and useful, they cannot achieve low cost, broadband-in-the home for two principal reasons. First, in order to achieve data rates above 2 Mb/s within the currently authorized 1 MHz bandwidth, a manufacturer would have to employ very complex linear modulation schemes, which greatly increase cost and reduce range. Second, it is extremely difficult to reach speeds of 10 Mb/s in the 1 MHz hopping channel bandwidth.

In addition, achieving data rates above 2 Mb/s under the current rules, even if achievable, would not be in the public interest. Under the existing rules, desired ranges could be achieved only by operating at the full 1 watt. Such an outcome would result in far more interference to other 2.4 GHz band users, especially DS systems, than would lower-power WBFH systems.

3. Other Licensed And Unlicensed Alternatives Do Not Provide A Reasonable Alternative to WBFH.

All bands below 2.4 GHz that might be considered for enabling broadband in the home are insufficient due to lack of total bandwidth, licensing restrictions, or other regulatory restrictions.

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[35] See Comments of Texas Instruments (FHSS is superior to DSSS in terms of performance and implementation costs); see also Comments of the University of Florida, Donovan Consulting.

While the 5 GHz UNII and ISM bands do have considerable potential for real-time video distribution in the home, the rules are written to encourage usage of at least 20 MHz at a time. This fact, combined with the propagation characteristics of 5 GHz, does not favor at all small portable "moderate" data rate appliances - in particular cordless telephones. Moreover, for the next several years the costs of manufacturing 5 GHz devices will be quite high for consumer applications.

Above 5 GHz, the choices for the home are even less appealing, due to both spiraling costs and poorer propagation characteristics.

C. WBFH Devices Will Save Consumers Billions Of Dollars.

WBFH devices can be constructed using essentially the same components as are used today in existing FH devices. Despite the use of the term "Wide Band FH" to describe 3 MHz or 5 MHz wide hopping channel bandwidth systems, these systems are still very much "narrow band" in terms of a radio transceiver implementation because the ratio of hopping channel bandwidth to carrier frequency (5/2450 = .002, or .2%) is still very small.

WBFH devices will vary slightly from existing 1 MHz devices. For robust and reliable performance, most WBFH systems likely will use a simple adaptive equalizer to combat what multipath interference might be encountered in typical home environments. In addition, dual hopping channel bandwidth systems, such as those planned by the HomeRF group, also may employ an additional IF channel filter and possibly an antenna diversity switch. The total additional material cost of a WBFH device compared to an existing FH device is expected to be less than $2.00 initially, and much less eventually.

In contrast, the difference in cost between WBFH devices and currently proposed high-speed alternatives is dramatic. Based on the HomeRF specification, WBFH devices

will have a semiconductor bill of materials cost of approximately $17 per radio.[36] Similar speed (11 Mb/s) DS products based on the IEEE 802.11b specification will need at least $40 in semiconductors per radio[37] and, even at this significantly higher cost, will not provide the high quality cordless telephony support or streaming media quality of service options available in WBFH products.

Furthermore, other necessary components also are much more expensive in the high speed DS case than in the WBFH case. When all costs are considered, the total bill-of-materials comparison is about $25 per radio for WBFH and at least $50 per radio for high speed DS.

For the consumer, the actual purchase price of radio networking devices is typically three to five times the bill-of-materials cost. WBFH devices, thus, offer savings of $50 to $100 per device for consumers, as well as substantially better broadband voice and data features.

CUBE estimates that a typical home will have several broadband devices: a broadband gateway, a few cordless handsets, a few networked PCs, and a few Internet appliances or gaming devices. When costs are aggregated across all such devices, the savings per home with WBFH will be substantial. More broadly, with more than 10 million homes predicted to be networked for broadband over the next five years,[38] the total savings to American consumers easily will number in the billions of dollars.

II. TECHNICAL CONSTRAINTS WILL NOT IMPEDE WBFH PERFORMANCE.

In their comments, opponents of WBFH systems - including, among others, a relatively small number of Bluetooth SIG members, IEEE 802.11, Intersil, Nortel, and WECA - imply that these systems will be incapable of meeting their performance objectives for a variety of technical reasons. First, some allege, WBFH systems will be

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[36] See Presentation of Dr. K.J. Negus, HomeNET '99, San Francisco, CA (July 28, 1999).
[37] This figure is based on data contained in an Intersil press release dated Sept. 23, 1999, together with additional cost estimates provided by Proxim.
[38] See Yankee Group press release (Oct. 20, 1999).

highly susceptible to multipath distortion.[39] As a result, they contend, WBFH systems will have to re-transmit large amounts of message traffic, thereby "using up" the increased bandwidth with repetitive transmissions rather than employing the bandwidth for increased throughput.[40] Second, they note, WBFH networks by necessity will have to employ overlapping channels. As a result, they argue, WBFH devices will cause highly objectionable levels of interference to one another, making them unusable for closely located or co-located networks.[41] Finally, they contend, WBFH devices will be highly susceptible to interference from other devices in the home (in particular, microwave ovens).[42] Again, they argue, this will undermine WBFH reliability and limit WBFH throughput.

As discussed in the following sections, each of these claims misstates or misapplies the relevant technical criteria, thereby resulting in gross overestimations of the potentially harmful effects of multipath, overlapping channels, and interference from non-WBFH devices. CUBE members and others who intend to bring WBFH products to market are confident that WBFH devices not only will work but will offer consumers benefits that no other technologies offer, but the Commission need not choose "winners or losers" or handicap the race. As long WBFH will not cause increased levels of interference to other users of the 2.4 GHz band - as Section IV demonstrates - the Commission should let the market assess the relative merits of competing systems.

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[39] "Multipath distortion" or "multipath fading" refers to the fact that, in an indoor environment, radio waves are reflected, refracted, and scattered and, as a result, often reach a receiver by multiple paths. Because path lengths differ, signal propagation time and attenuation vary across paths. As a result, when the receiver combines the multiple received signals, it generates a distorted version of the original message. If the distortion is sufficiently significant, the received signal is rejected as indecipherable and the original signal must be retransmitted.

[40] See, e.g., Comments of Intersil, WECA.

[41] See, e.g., Comments of Intersil, IEEE 802.11.

[42] See, e.g., Comments of AHAM, Fusion Lighting, IMPI.

A. MULTIPATH DELAY SPREAD EFFECTS WILL NOT LIMIT PERFORMANCE.

Contrary to the opponents' claims, multipath distortions will not pose an insurmountable problem for WBFH in-home networks.[43] The home is a highly absorptive environment that is completely different from the reflective office environment that the IEEE 802.11b standards process focused upon. In the home, the large number of walls and typical wall construction serve to attenuate radio signals from one relatively small room to another. In the office, in contrast, large open spaces and metal walls and furniture can create reflective situations with significant delay spreads as range increases. As a result, while the maximum delay spread in most office environments is in the range of 40-70 ns,[44] the maximum delay spread in a home environment is substantially lower.

Fortunately, some studies of delay spread in the home already exist.[45] A simplified view of these studies produces about 10 ns delay spread in a typical residential room. As signals propagate across multiple rooms, the delay spreads tend to add in a root mean square basis. Thus, it is very difficult in the vast majority of U.S. homes to find delay spreads greater than 25 ns from one end of the home to the other. Indeed, within the home, signal attenuation due to absorption by walls is a far more common problem than is delay spread.

The opponents of the Commission's proposal also have asserted that somehow the use of 4FSK modulation with limiter and analog discriminator receiver architecture will preclude low cost equalization of the typical delay spreads that will be encountered. Again, nothing could be further from the truth. It actually is very

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[43] Indeed, the "multipath concern" was set out in a letter to the Commission from Home Wireless Networks (HWN) prior to issuance of the NPRM. Ironically, however, HWN realized that their original concerns for delay spread limitations for WBFH systems were in fact unfounded and filed comments effectively withdrawing its earlier letter.

[44] See "Delay Spread Requirements for Wireless Networks in the 2.4 GHz and 5 GHz Bands," Document IEEE P 802.11-97/125 (Nov. 1997).

[45] E.g. "Residential Indoor RF Channel Characterization," MacLellan, et.al., Proceedings of the IEEE 43rd Vehicular Technology Conference, at 210-213 (May 18-20, 1993); "RF Environment," Ed McDonnell, HP Labs Report (Oct. 1999).

straightforward to build an adaptive equalizer capable of half bit period correction with limiting receivers while adding less than $.25 to the cost of a baseband silicon IC. At 10 Mb/s, this means up to 50 ns of delay spread tolerance theoretically, and easily greater than 40 ns in a practical, low cost implementation. Since this capability exceeds the delay spreads likely in the residential environment, the opponents' arguments are misplaced. The reality for almost every home is that signal attenuation will limit the useful range of 10 Mb/s well before multipath distortion or delay spread becomes a problem.

B. PARTIALLY OVERLAPPED CHANNELS WILL NOT LIMIT PERFORMANCE IN THE HOME.

The opponents of the Commission's proposal assert that when a certain type of limiter and analog discriminator receiver implementation are used, the interference of one WBFH network to another similar network will be considerably worse than two FH networks, where the channels are precluded from partially overlapping.[46] Once again, however, the opponents greatly exaggerate the concern.

The basis of the opponents' argument is the response characteristic of the analog discriminator to signals offset from the tank circuit center frequency. Using a combination of oversimplified analysis and measured data on existing FH products, they assert that partially overlapping channels can have signal-to-interference ratios that are up to 7 dB worse than fully overlapping co-channel interference.[47] They further present dire eye diagrams and dramatic tables of results to illustrate serious interference problems. Notably, these all are made with the channel filtering removed. No one, however, even would consider building a wireless LAN with no channel filtering.

Detailed numerical simulations and measurements of products made by CUBE members show that, at most, there will be a 3 dB increase in the signal-to-interference ratio due to partial overlap on a discriminator. The real question, of course, is what

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[46] See, e.g., Comments of Intersil, IEEE 802.11.
[47] See, e.g., Comments of Intersil, Aironet.

effect would 3 dB of increased self-interference - or even 7 dB, if the opponents' dire predictions were to hold true - have on systems operating with a 100 dB total link budget in real home environments.

The answer to this question is apparent from the extensive simulation work of the HomeRF Technical Committee, which was presented to the Commission prior to issuance of the NPRM. The HomeRF group analyzed the effects of partially overlapping channels on WBFH devices while making far more pessimistic assumptions than this miniscule 3 dB discriminator effect. To be conservative, the HomeRF Technical Committee assumed both a uniform distribution of energy in the WBFH transmit channel and that interfering networks would be active at the 5 MHz hopping channel width 100% of the time.

Despite the use of these highly pessimistic assumptions (which dwarf the 3 dB discriminator effect), the HomeRF group found that throughput degradation for detached family homes with 5 MHz WBFH systems in both the target home and all surrounding homes in the neighborhood effectively was zero. In the case of multi-unit dwellings, where the target unit and all surrounding units were 5 MHz WBFH systems, almost no degradation of 5 MHz wide mode throughput was seen until the extreme situation of corner to opposite corner separation occurred. Interestingly, the effect actually was worse if the surrounding units had either DS or FH systems operating in compliance with the IEEE 802.11 specifications.

In sum, the technical evidence demonstrates that partially overlapping channels will have no significant negative effects compared to the performance of existing DS or FH systems.

C. WBFH Systems Will Be Able To Tolerate Any Interference Likely To Be Present In The Home.

Another concern raised by opponents of the Commission's proposal revolves around the susceptibility of WBFH devices to non-WBFH sources of interference in the