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DISPATCH

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

In the Matter of	)	
	)	
Amendment of the Commission's Rules to	)	ET Docket No. 96-102
Provide for Operation of Unlicensed NII	)	RM-8648
Devices in the 5 GHz Frequency Range	)	RM-8653

MEMORANDUM OPINION AND ORDER

Adopted: June 17, 1998 **Released: June 24, 1998**

By the Commission:

INTRODUCTION

1. By this action, the Commission addresses two Petitions for Reconsideration and a Petition for Reconsideration and Clarification ("Petitions") of the *Report and Order*[1] ("*R&O*") in this proceeding filed on March 3, 1997 by Apple Computer, Inc, ("Apple"), Hewlett-Packard Company ("H-P"), and the Wireless Information Networks Forum ("WINForum"), respectively. Specifically, we amend Part 15 our rules to permit fixed, point-to-point Unlicensed National Information Infrastructure ("U-NII") devices in the 5.725-5.825 GHz band to operate with one watt ("W") maximum transmitter output power and directional antennas of up to 23 dBi gain. Additionally, we amend our rules to specify transmit power limits in the form of a logarithmic equation as a function of channel bandwidth. We also clarify our rules regarding unwanted emissions and specify these limits in terms of absolute radiated power levels. Further, this action clarifies and addresses other issues raised in the petitions regarding the operation of, and regulations governing, U-NII devices. The actions taken herein will add to the flexibility and capability of U-NII operations without causing an increase in harmful interference to incumbent operations sharing the same spectrum.

BACKGROUND

2. On January 9, 1997, the Commission adopted a *R&O* in ET Docket No. 96-102 which amended Part 15 of our rules to make available 300 megahertz of spectrum at 5.15-5.35 GHz and 5.725-5.825 GHz for use by a new category of unlicensed equipment, called U-NII devices. These devices are intended to provide high speed wireless digital communications on an unlicensed basis. The *R&O* stated that U-NII devices will support the creation of new wireless local area networks ("LANs") and will facilitate wireless access to

[1] *See Report and Order*, ET Docket 96-102, 12 FCC Rcd 1576 (1997), hereinafter *R&O*.

the National Information Infrastructure ("NII").[2] In order to permit flexibility in the design and operation of these devices, the *R&O* adopted those technical rules found to be minimally necessary to prevent interference to other services and to ensure that the spectrum is used efficiently. Additionally, the rules set forth in the *R&O* were intended to foster the development of a broad range of new devices and service offerings that will stimulate economic development and the growth of new industries.

3. In response to the *R&O*, on March 3, 1997, Apple, H-P and WINForum filed petitions requesting that we reconsider certain aspects of the *R&O* and clarify other rules adopted in this proceeding. Apple requests primarily that we amend the rules to permit U-NII devices in the 5.25-5.35 GHz and 5.725-5.825 GHz bands to operate with power and antenna gain similar to those permitted for unlicensed spread spectrum operations in the 2400-2483.5 MHz and 5.725-5.850 GHz bands, respectively. H-P requests, for U-NII operations in the 5.15-5.25 GHz band, an increase in the maximum permitted power from 200 milliwatts ("mW") Equivalent Isotropically Radiated Power ("EIRP") to 1 W EIRP, which is the maximum power level permitted in Europe for similar unlicensed network ("HIPERLAN") devices operating in the band. H-P also supports WINForum's petition, addressed immediately below.

4. WINForum requests reconsideration of the rules governing U-NII power in each of the U-NII frequency bands. First, WINForum states that the U-NII power limits should generally be specified as a logarithmic function of bandwidth, instead of as specific transmit output power levels per megahertz of bandwidth, to encourage broadband U-NII use of this spectrum. Second, WINForum requests that the Commission permit a 3-dB power fluctuation tolerance in any one megahertz of bandwidth, in recognition that most modulation envelopes are not "spectrally flat." Third, WINForum requests clarification of the unwanted U-NII emission limitations adopted in the *R&O*. Fourth, WINForum requests that in our rules we clarify equipment measurement procedures and adopt appropriate definitions for "power spectral density," "peak power spectral density," "transmit power," and other technical parameters to account for the characteristics of digital signals and for the inherent randomness generated by the measurement of wideband signals with instruments having narrowband filters. Finally, WINForum requests that we clarify in our rules that U-NII devices are required to use digital modulation techniques.

5. Seven parties, most with interests in incumbent operations in the 5 GHz band, filed comments in response to the petitions. Generally, these comments oppose any increase in permitted power, any relaxation of unwanted emission requirements for U-NII operations, and any action that would have the effect of increasing the likelihood that U-NII devices

[2] The National Information Infrastructure or NII is a group of networks, including the public switched telecommunications network, radio and television networks, private communications networks, and other networks not yet built, which together will serve the communications and information processing needs of the people of the United States in the future.

would cause harmful interference to incumbent operations.

DISCUSSION

A. Power and Antenna Issues.

6. Throughout this proceeding, one of the primary issues has been the determination of appropriate power and antenna limits for U-NII devices. Due to a desire to protect different types of incumbent operations in each of the three 100 megahertz segments available for U-NII operations and to a concomitant desire to address a variety of networking needs,[3] the *R&O* adopted different power and antenna limits for each of the three 100 megahertz segments. Specifically, the *R&O* established for U-NII devices the following peak power spectral density ("PSD") limits[4] and maximum peak power and antenna gain limits for each band: a) in the 5.15-5.25 GHz band, a 2.5 mW/MHz peak PSD limit and a maximum peak transmitter output power limit of 50 mW with an associated maximum antenna gain of 6 dBi, which equates to 200 mW EIRP in a 20 megahertz channel; b) in the 5.25-5.35 GHz band, a 12.5 mW/MHz peak PSD limit and a maximum peak transmitter output power limit of 250 mW with up to 6 dBi gain, which equates to 1 W EIRP in a 20 megahertz channel; and c) in the 5.725-5.825 GHz band, a 50 mW/MHz peak PSD limit and a maximum peak transmitter output power limit of 1 W with up to 6 dBi gain, which equates to 4 W EIRP in a 20 megahertz channel.[5] These power requirements were also intended to encourage the use of the U-NII bands for broadband operations and to ensure that the power transmitted by U-NII devices is spread evenly over the emission bandwidth. Additionally, to permit manufacturers flexibility in designing U-NII devices, the *R&O* adopted rules permitting operations with antenna gains exceeding 6 dBi. In such cases, the permitted transmit power and PSD of the device must be reduced by the same number of decibels that the gain exceeds 6 dBi. This will permit U-NII devices to employ highly directional antennas to focus its transmitted power in a particular direction, while not permitting the device to increase its potential to cause interference.

7. In its petition, WINForum states that the *R&O*'s power rules inadvertently favor narrowband systems because they specify PSD increments in one megahertz segments. That is, a device that operates within a 250 kilohertz channel would be permitted the same power as a device operating in a one megahertz channel. To remedy this, WINForum proposes that the transmit power specification for U-NII devices be expressed as a logarithmic equation dependent on bandwidth, *i.e.*, (X dBm + 10 log B), where B is the 26 dB bandwidth

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[3] *I.e.*, local area networks ("LANs"), campus networks and community networks.

[4] These power spectral density requirements are required to be measured with a spectrum analyzer having a minimum resolution bandwidth of 1 megahertz. *See* 47 C.F.R. § 15.405(a)(5).

[5] *See R&O* at ¶ 20.

in megahertz.[6]

8. *Comments.* The commenting parties support WINForum's proposal to specify transmit power limits as a function of bandwidth. Specifically, the National Telecommunications and Information Administration ("NTIA") supports WINForum's proposal because the proposed rule would not increase the maximum power output levels adopted in the *R&O*, but would prevent narrowband signals from operating at higher PSD than wideband signals. NTIA is concerned that narrowband signals operating at higher PSD than wideband could result in increased interference to Government systems operating in the same band.[7]

9. *Decision.* We are adopting WINForum's proposal of expressing the transmit power for U-NII devices as a logarithmic equation dependent on bandwidth. This action will not increase the maximum power permitted by U-NII devices, but merely scale permissible maximum power to the bandwidth used by the U-NII device. While this action would not preclude narrowband U-NII devices, it would prevent narrowband devices from operating at the same power as devices with wider bandwidths. We believe this change will facilitate spectrum sharing among the various U-NII devices which may operate with different bandwidths. Further, because a new term (B) is specified as the emission bandwidth, we are adding a definition in Section 15.403 for this term. The specific logarithmic equations we are adopting for each band are given below in our decisions regarding other power and antenna requests by Petitioners.

10. Additionally, Petitioners request that the power and antenna limits applicable to each of the three 100 megahertz segments be eased. Petitioners argue that increasing the permitted power and eliminating the power reduction for high gain antennas will benefit U-NII operations by facilitating flexibility and longer distance communications. However, incumbent interests argue that any increase in power or relaxation of the power reduction for high gain antennas will result in increased harmful interference potential to their operations and, therefore, the petitions should be denied.

11. Finally, because each of the three 100 megahertz U-NII segments have a different spectral environment, we will evaluate the power and antenna requests for each band separately. As described in detail below for each of the three 100 MHz band segments available for U-NII operations, we have decided to deny requests to ease power and antenna limits for U-NII devices at this time except for point-to-point links in the 5.725-5.825 GHz band. We pledge, however, to work with industry, consumers, government agencies, and other interested parties to closely monitor whether these limits can be eased in the future. For each of the U-NII band segments, we will pay particular attention to the extent of deployment

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[6] *See* WINForum Petition at 8.

[7] *See* NTIA Comments at 5.

and demand for U-NII and other devices and systems; actual spectrum sharing experiences; developments in technology that would improve sharing; and relevant regulatory changes in other countries.

12. 5.15-5.25 GHz band. In the *R&O*, we adopted a relatively low power limit, 200 mW EIRP, for U-NII devices in the 5.15-5.25 GHz band which we found to be sufficient to achieve short range LAN communications and to be low enough to facilitate spectrum sharing with Mobile Satellite Service ("MSS") feeder link operations. We stated that we may reassess the technical standards for this band if the spectrum sharing relationship between U-NII devices and MSS operations materially changes or if, in response to a possible proliferation of higher power HIPERLAN devices in Europe, MSS systems are designed to more robust specifications and therefore could also withstand higher power U-NII signals.[8] In its petition, H-P argues that the Commission should now increase the U-NII maximum power limit in this band to 1 W EIRP.[9] H-P states that this higher power limit will facilitate more robust and longer distance U-NII operations, as well as enable manufacturers to build U-NII devices that can operate across the entire 5.15-5.35 GHz band. H-P adds that, in Europe, a 1 W EIRP limit will apply to HIPERLAN networking devices in this frequency band.[10] Therefore, H-P concludes, adoption of this same limit for U-NII devices in the band would enable manufacturers to more readily develop products suitable for both United States and European markets.

13. *Comments*. The MSS proponents support adherence to the power and antenna limits adopted in the *R&O* and oppose H-P's requested power increase.[11] Airtouch Communications, Inc. ("Airtouch") argues that U-NII operations with increased power in the 5.15-5.25 GHz band will likely result in decreased communications capacity for the Globalstar MSS satellite system, which will employ feeder links in the band. Airtouch further states that Europe has not coalesced upon a single power limit for HIPERLAN operations and is still considering adopting power levels as low as 10 mW EIRP.[12] NTIA opposes H-P's power increase request as not having adequately considered the potential impact on Government

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[8] *See R&O* at para. 96.

[9] *See* H-P Petition at 2. Specifically, H-P requests that we increase the maximum peak transmitter output power limit in the lower band to 250 mW with up to 6 dBi antenna gain, which equates to a 1 W EIRP limit.

[10] H-P states that twenty European countries have already committed to the terms of the European Telecommunications Standards Institute ("ETSI") HIPERLAN standard, which includes a 1 W EIRP limit. *See* H-P Reply at 2.

[11] MSS proponents include: Loral/Qualcomm Licensee, Inc.; Airtouch Communications, Inc.; ICO Global Communications and Comsat Corporation.

[12] *See* Airtouch Opposition at 5.

safety-of-life operations in the band.[13] ICO Global Communications and Comsat Corporation ("ICO/Comsat") and Loral/Qualcomm Licensee, Inc. ("L/Q") argue that H-P and WINForum have failed to offer sound technical arguments or new information to justify changing the Commission's decision in the *R&O*.[14] Specifically, they argue that the issue of harmonizing the U-NII and HIPERLAN power limits was raised in the *Notice of Proposed Rule Making* ("*NPRM*")[15] and addressed in the *R&O*, but H-P has provided no new information to justify reconsideration of this issue. Further, L/Q and NTIA point out that the HIPERLAN standard recommends three different power levels from 10 mW to 1 W EIRP and claim that manufacturers could easily design devices with the capability of meeting both the applicable HIPERLAN limits for use in Europe and the U-NII power limit for use in the United States. Finally, the MSS proponents argue that H-P has not explained why consumers would not be well served by the power limits adopted in the *R&O*, given that devices complying with those limits will be adequate for LAN operations and that users who need additional power may use the 200 megahertz of spectrum in the upper U-NII bands.

14. H-P responds that its petition relies on developments that occurred after the comment cycle in this proceeding. Additionally, H-P argues that it is not required to submit a technical analysis to support its request to increase the U-NII power limit because it does not rely on theoretical claims of spectrum sharing capability between U-NII and MSS operations. Rather, H-P contends that its request relies on the expectation that higher power networking devices will be operating in Europe and on the concomitant necessity for global MSS operations to be robustly designed to withstand these higher powered signals in the band. H-P concludes that it would serve no useful purpose for the Commission to defer authorizing in the United States U-NII devices with power equivalent to that which will be generally permitted in Europe.[16] WINForum supports H-P's request to increase U-NII power in the 5.15-5.25 GHz band, arguing that it conducted a spectrum sharing analysis which demonstrates that the effect of higher powered U-NII devices on MSS feeder links would be virtually undetectable.[17] WINForum further argues that the MSS proponents have not provided any technical analysis to refute its sharing analysis. Finally, WINForum argues that MSS proponents should have designed their systems to tolerate any hypothetical level of noise generated by 1 W radio networking devices, inasmuch as the HIPERLAN specification was underway and in circulation well before spectrum was allocated to MSS feeder links at the

[13] *See* NTIA Comments at 17.

[14] *See* ICO/Comsat Opposition at 2; L/Q Opposition at 4-5 and Reply at 2.

[15] *See Notice of Proposed Rule Making*, ET Docket No. 96-102, 11 FCC Rcd 7205 (1996).

[16] *See* H-P Reply at 3.

[17] *See* WINForum Reply at 7 and Attachment 1.

1995 World Radiocommunications Conference ("WRC-95").[18]

15. *Decision.* While we acknowledge that several European countries permit HIPERLAN devices to operate with up to 1 W EIRP, we find that a more conservative power limit for U-NII operations in this band is appropriate at this time. As stated in the *R&O*, the technical limits for the 5.15-5.25 GHz band will ensure that millions of U-NII devices can co-exist and share spectrum with MSS feeder links. Although WINForum's analysis shows that a substantial number of 1 W EIRP U-NII operations would also be able to share this band with MSS feeder links, we find that it is too early to predict reliably the variety and number of U-NII operations that will use the band.[19] We continue to believe that the 200 mW EIRP limit adopted in the *R&O* will enable short range wireless LAN applications in this band without causing interference to MSS operations. The *R&O* identified the 5.15-5.25 GHz band as intended home for indoor short range networking devices and U-NII devices with higher power requirements may utilize the other U-NII bands.[20] In accordance with our decision in paragraph nine above to establish transmit power limits as a logarithmic function dependent on bandwidth and our decision not to increase the applicable power limits, we are amending our rules to require that the peak output power of U-NII devices in the 5.15-5.25 GHz band shall be limited to the lesser of 50 mW or 4 dBm + 10logB, where B is the 26-dB emission bandwidth in MHz, in conjunction with a permitted antenna gain of up to 6 dBi.

16. Finally, as indicated in the paragraph 11 above and the *R&O*, we may reassess these limits in the future if the spectrum sharing relationship between U-NII devices and MSS operations materially changes or if, in response to a possible proliferation of higher power HIPERLAN devices in Europe, MSS systems are designed to more robust specifications and therefore could also withstand higher power U-NII signals.[21] In the interim, we do not believe this power level will necessarily hinder the compatibility of U-NII and HIPERLAN devices because it is not yet clear whether HIPERLAN devices will use the 1 W power permitted or one of the lower power options and because devices can easily be designed to operate at varying power levels.

17. <u>5.25-5.35 GHz band</u>. The power and antenna limits adopted in this band were intended to accommodate communications within and between buildings, such as envisioned for campus-type networks, and to facilitate power consistency with the 1 W EIRP limit used

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[18] *See Final Acts of the World Radiocommunication Conference, Geneva,* 1995 (ITU 1996).

[19] For example, while we agree with WINForum's analysis that most U-NII devices would likely operate with a duty cycle, at this point it is impossible to predict the extensive uses that would be permitted under the U-NII rules, many of which may operate continuously.

[20] *See R&O* at para. 44.

[21] *See R&O* at para. 96.

for HIPERLAN devices.[22] In its petition, Apple requests that fixed, point-to-point U-NII devices in this band be permitted to use directional antennas without gain limitations, subject to a reduction of 1 dB of transmitter power for every 3 dB that the antenna gain exceeds 6 dBi.[23] Apple requests this additional antenna flexibility to permit U-NII devices to achieve longer range community networking links. Apple argues that since the Commission removed the directional antenna limits for fixed, point-to-point unlicensed spread spectrum devices at 2.4 GHz and 5.8 GHz, then similar action should be taken for U-NII devices in the 5.25-5.35 GHz and 5.725-5.825 GHz bands, respectively. Apple contends that the *Report and Order* in ET Docket 96-8 ("*Spread Spectrum R&O*")[24] recognized the benefit of long range unlicensed operations and acknowledged that directional antennas can significantly reduce the potential for harmful interference to other radio operations.[25] Further, Apple argues that there are no regulatory parity problems between longer range unlicensed and licensed operations.

18. *Comments*. Regarding the 5.25-5.35 GHz band, NTIA comments that an ITU-R study shows that U-NII devices meeting the emission limits adopted in the *R&O* would not interfere with spaceborne sensors in the Earth Exploration Satellite Service ("EESS") which use this band.[26] However, NTIA points out that this study assumes that only one percent of the U-NII devices in this frequency range would operate outdoors. NTIA claims that Apple's proposed additional antenna gain will encourage additional outdoor use in the form of community networks which could increase the amount of interference to sensitive space research operations.[27] NTIA opposes Apple's request for this band and states that Apple has not provided any interference studies to support its request and has not addressed any potential increased interference to the EESS or the adjacent aeronautical radionavigation band.

19. *Decision*. We believe that the power and antenna limits adopted for the 5.25-5.35 GHz band will facilitate the development of a wide variety of U-NII devices. The 1 W EIRP power limit will permit a high degree of frequency reuse, while also permitting sufficient power to achieve reliable indoor networking as well as some outdoor campus-type networking. Additionally, this power level is equivalent to the HIPERLAN power level. We

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[22] *See R&O* at para. 45.

[23] *See* Apple Petition at 4.

[24] *See Report and Order*, ET Docket No. 96-8, FCC 97-114, 62 FR 26239, released April 10, 1997.

[25] *See* Apple Reply at 3.

[26] *See* NTIA Comments at 14

[27] NTIA explains that signals from indoor U-NII devices would be subject to 20 dB of building attenuation, which would permit more devices to operate without interfering with spaceborne receivers. But NTIA explains, outdoor U-NII devices would transmit signals that are not subject to such building attenuation and, further, these signals would be scattered and reflected in a manner to cause an increased level of interference to spaceborne operations.

do not believe that the lessening of antenna restrictions on unlicensed spread spectrum operations at 2.4 GHz and 5.8 GHz justifies similar treatment for U-NII devices in this frequency band because each frequency band has a different interference environment. However, we will consider higher gain antennas for U-NII devices in the 5.725-5.825 GHz band for longer range community networking below. Additionally, we acknowledge that no analysis has been provided to support U-NII operations with unlimited gain antennas in this band or to demonstrate that they would not cause interference to EESS operations. Accordingly, we affirm our decision in the *R&O*, as modified by paragraph nine, above, that U-NII operations in the 5.25-5.35 GHz band must comply with a peak transmitter power that is the lesser of 250 mW or 11 dBm + 10logB, where B is the 26-dB emission bandwidth in MHz, with a permitted antenna gain of up to 6 dBi. Further, as stated in the *R&O*, higher gain antennas will be permitted provided there is a corresponding reduction in transmitter output power of one dB for each dB that the transmit antenna gain exceeds 6 dBi.

20. 5.725-5.825 GHz band. The *R&O* adopted rules permitting U-NII operations with power and antenna limits equivalent to that permitted for unlicensed spread spectrum operations in this band. We found that these limits would facilitate community networking communications over a range of several kilometers. Apple argues that we should relax these limits so as to allow fixed, point-to-point U-NII devices in this band to operate with unlimited gain antennas, as was recently permitted for unlicensed spread spectrum devices in this frequency range.[28] In support of its request, Apple argues that the *Spread Spectrum R&O* recognized the benefits of longer range unlicensed operations and the usefulness of directional antennas in allowing transmission systems to overcome background noise to achieve reliable communications.[29] Additionally, Apple contends that the *Spread Spectrum R&O* recognized that the 5.8 GHz band is uniquely well-suited for the operation of long range unlicensed operations using directional antennas, due to the relatively low number of users, particularly mobile users, in the band and the limited potential for harmful interference arising from the use of highly directional antennas. Apple asserts that each rationale in the *Spread Spectrum R&O* for allowing high gain antennas for Part 15 spread spectrum devices applies equally well for U-NII devices.

21. *Comments.* NTIA supports the use of higher gain antennas for fixed, point-to-point U-NII devices in the 5.725-5.825 GHz band to facilitate longer range communicating links to connect schools, libraries, hospitals and clinics. NTIA, however, is concerned that high power Government radar systems could interfere with these unlicensed devices,

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[28] In its petition, Apple originally requested that the Commission consider permitting U-NII devices to operate with highly directional antennas at the same time as it considered in ET Docket No. 96-8 whether to permit such high gain antennas for unlicensed spread spectrum operations. However, the *Spread Spectrum R&O* was adopted soon after Apple filed its petition, and, in its reply comments, Apple asks that in the instant proceeding we amend the rules to afford fixed, point-to-point U-NII devices in the 5.725-5.825 GHz band the same antenna flexibility as that permitted unlicensed spread spectrum devices in this band. *See* note 24, *supra*.

[29] *See* Apple Reply at 3.

particularly in cases where the radar transmitter is within the main lobe of a highly directional U-NII receiving antenna. Rather than permitting unlimited gain antennas for U-NII devices, NTIA recommends that we permit fixed, point-to-point U-NII devices in the upper band to operate at 1 W transmitter power with directional antennas of up to 23 dBi gain.[30] NTIA also suggests that antenna gain greater than 23 dBi be permitted as long as a 1 dB reduction in power is required for each dB of antenna gain in excess of 23 dBi. NTIA further recommends that U-NII transmitters utilizing antennas that exceed 6 dBi be limited to fixed, point-to-point operations only, excluding such operations as point-to-multipoint systems, omni-directional applications, and multiple collocated transmitters transmitting the same information. It acknowledges that permitting higher gain antennas can reduce interference problems in some cases for fixed, point-to-point links and argues that its proposal would promote antenna parity between unlicensed point-to-point spread spectrum and U-NII operations in this band. Finally, NTIA suggests that the U-NII rules expressly state: "The Commission strongly recommends that parties employing U-NII devices to provide critical communications services should determine if there are any nearby Government radar systems that could affect their operation."[31]

22. AT&T Corp. ("AT&T") opposes the allowance of higher gain antennas in unlicensed bands that would facilitate long range communications because it claims this will increase interference problems. Additionally, AT&T argues that these long range unlicensed communications could compete with licensed services which had to pay for spectrum access through the auctioning of licenses. AT&T argues that allowing competition between licensed services and unlicensed operations is a violation of regulatory parity.[32] The American Radio Relay League, Inc. ("ARRL") argues that longer range links will cause interference to amateur operations and that Apple has not submitted interference studies to support its request for unlimited gain antennas in this band. Additionally, the ARRL argues that long range links are a significant departure from the precepts of Part 15 regulations. Specifically, ARRL contends that the Communications Act requires that the interference potential of unlicensed devices be subject to "reasonable regulation," which would require that unlicensed devices operate in a manner that is not likely to cause interference to a licensed service.[33]

23. Responding to arguments that higher gain antennas would increase interference to licensed operations, Apple claims that the *Spread Spectrum R&O* supports antenna

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[30] *See* NTIA Comments at 12.

[31] The purpose of this statement is to account for NTIA's concern that its high power Government radar operations could cause interference to U-NII devices.

[32] *See* AT&T Opposition at 2.

[33] *See* ARRL Comments at 9.

directionality as a means of reducing, not increasing, interference.[34] Additionally, Apple states that the U-NII *R&O* rejects the claim that regulatory parity requires the licensing of all longer-distance links. It asserts that rather than restricting the consumer's options by protecting the investment of auction winners, the Commission should stand by its decision to permit the development of longer range unlicensed systems. Additionally, Apple responds that the ARRL has not demonstrated that U-NII devices present any real threat of interference to Amateur services. It also argues that the ARRL has failed to demonstrate that non-spread spectrum U-NII transmitters using highly directional antennas pose any greater threat of interference to Amateur operations than do unlicensed spread spectrum transmitters using such antennas. Apple supports a policy of letting the marketplace, rather than regulations, decide which technologies will succeed or will fail. Finally, Apple argues that unlicensed operations are different from licensed operations in that they operate on an "at sufferance" basis and cannot assure the quality of service to consumers that licensed service providers offer on protected or exclusively licensed spectrum.

24. *Decision.* As reflected in the *Spread Spectrum R&O*, the Commission recognizes that there are certain instances where being able to establish radio links without the delays and costs associated with formal frequency coordination and licensing is in the public interest.[35] The Commission also continues to believe that the 5.8 GHz band is well suited for unlicensed fixed, point-to-point U-NII links employing high gain antennas because of the low number of mobile uses in this band. Further, we find that permitting the fixed point-to-point unlicensed operations in this band to use antennas with gains similar to that permitted spread spectrum devices is desirable and would benefit consumers by providing them the option of choosing between more robust, but lower speed, spread spectrum operations or higher speed, but less robust, U-NII operations to accomplish their desired communications. We find that issues of regulatory parity and unfair competitiveness raised by AT&T are not a basis for concern at this time in view of the limited scope of this decision applicable only to U-NII devices in these bands. The status of unlicensed devices is not being altered by this item in that they continue to operate without protection from interference caused by other devices or authorized services and are not entitled to exclusive use of the spectrum in a given area, as are most licensed services.

25. Nevertheless, at this time it is difficult to predict the extent of proliferation of the various types of U-NII devices which may operate in the 5.725-5.825 GHz band. Therefore, we find it is appropriate for now to adopt NTIA's more conservative proposal to permit fixed, point-to-point U-NII devices to operate with up to 1 W transmitter power and directional antennas with up to 23 dBi gain. We will limit 1 W U-NII transmitters utilizing antennas that exceed 6 dBi to fixed, point-to-point operations only, and they may not be used, for example, for point-to-multipoint systems, omni-directional applications, or multiple

[34] *See* Apple Reply at 4.

[35] *See Spread Spectrum R&O* at para. 11.

collocated transmitters transmitting the same information. To permit additional flexibility for fixed, point-to-point U-NII operations, we will permit antenna gains greater than 23 dBi as long as a 1 dB reduction in transmitter output power and PSD is employed for each 1 dB of antenna gain in excess of 23 dBi. We find that these fixed, point-to-point U-NII parameters should permit community networking links of several miles, and we observe that 23 dBi U-NII antenna manufacturers should be able to utilize readily available technology to lower costs. We note that several unlicensed fixed, point-to-point spread spectrum devices typically use directional antennas with gain in the 23 dBi range and we believe this is an appropriate permitted gain level. Additionally, we note that the fixed, point-to-point U-NII operations will not pose any higher interference potential than that posed by the unlicensed spread spectrum devices already permitted in this band. We point out that U-NII operations in this band that do not qualify as fixed, point-to-point systems must comply with the existing U-NII limits for this band adopted in the *R&O*.

26. Accordingly, U-NII devices in the 5.725-5.825 GHz band generally will be governed by a peak transmitter power of the lesser of 1 W or 17 dBm + 10logB, where B is the 26-dB emission bandwidth in MHz, with a permitted antenna gain of up to 6 dBi. Additionally, fixed, point-to-point U-NII devices operating in this band may employ transmitting antennas with directional gain up to 23 dBi without any corresponding reduction in the transmitter peak output power or peak power spectral density. If transmitting antennas of directional gain greater than that specified above are used, both the peak transmit power and the peak PSD must be reduced by the amount in dB that the directional gain of the antenna exceeds that specified above. Finally, we are placing NTIA's suggested language in Section 15.407(a)(3) of the U-NII rules advising users of the devices to check for government operations in the 5.725-5.825 GHz in order to avoid interference situations.[36]

B. Power Spectral Density.

27. As stated above, the R&O adopted peak PSD limits for each of the three U-NII bands to ensure that the power transmitted by U-NII devices is evenly spread over the emission bandwidth.[37] In their petitions, WINForum and Apple request that we make certain modifications to these limits. WINForum argues that there are variations in the power level of most signals across their bandwidth. That is, most digital modulation techniques exhibit a non-constant modulation envelope[38] resulting in very short random fluctuations in power (both up and down) across the envelope. It argues that even though these random fluctuations may be on the order of 3 to 6 dB, they do not increase the interference potential of the device because of their extremely short duration and because of the averaging effect of the up and

[36] *See* Section 15.407(a)(3) of Final Rules in Appendix A.

[37] *See R&O* at para. 49.

[38] A signal envelope is the boundary of a family of curves obtained by varying a parameter of a wave. *See Telecommunications: Glossary of Telecommunication Terms*, Federal Standard 1037B, (1991).

down power fluctuations. To account for these variations, WINForum requests that the Commission permit U-NII devices a 3-dB tolerance in peak PSD in any given one megahertz segment.[39] WINForum argues that regardless of variations in a signal's PSD across its bandwidth, its total power output would meet the U-NII limits. WINForum also argues that since its request would not increase a device's overall maximum power output, its request would not result in an increased interference potential.

28. In its petition, Apple requests that we amend the PSD for U-NII devices in the 5.25-5.35 GHz and 5.725-5.825 GHz bands to permit them to operate at maximum power in a two megahertz bandwidth rather than a 20 megahertz bandwidth. Specifically, Apple requests that U-NII devices in the 5.25-5.35 GHz band be permitted to operate at a PSD of 125 mW/MHz to achieve maximum power in a two megahertz bandwidth. Similarly, Apple states, the PSD for U-NII devices in the 5.725-5.825 GHz should be amended to 500 mW/MHz.[40] However, in its reply comments, Apple instead requests that the PSD for U-NII devices in the 5.25-5.35 GHz and 5.725-5.825 GHz bands be amended to match those adopted for unlicensed spread spectrum operations.[41] Specifically, Apple requests that U-NII devices in these bands be permitted a PSD of 6.3 mW (8 dBm) in any 3 kilohertz bandwidth. This would permit U-NII devices to operate at maximum power in a minimum bandwidth of approximately 120 kilohertz and 500 kilohertz for the 5.25-5.35 GHz and 5.725-5.825 GHz bands, respectively.[42] Apple argues that the PSD limits in the *R&O* are too restrictive and will not allow U-NII devices to achieve long range communications. Apple also argues that the tradeoffs between U-NII and unlicensed spread spectrum systems are complex and that permitting parity in PSD between these types of systems would allow designers and users flexibility in creating technical solutions to meet particular requirements.[43]

29. *Comments.* Comments from several incumbent parties oppose WINForum's request for 3 dB of tolerance in meeting U-NII PSD requirements. Specifically, NTIA, Airtouch and L/Q Licensee, Inc. argue that grant of the request would permit U-NII devices to operate with twice the power permitted by the *R&O* and, thus, would double their potential

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[39] *See* WINForum Petition at 8.

[40] *See* Apple Petition at 6. Apple's requested maximum PSD for the 5.25-5.35 GHz and 5.725-5.825 GHz bands are 10 times the level adopted in the *R&O* and would permit U-NII operations to transmit maximum power in a two megahertz channel instead of the currently required 20 megahertz channel for maximum power transmission.

[41] *See* Apple Reply at 6.

[42] These proposed PSD limits would be 167 times higher than those adopted in the *R&O* for the 5.25-5.35 GHz band and 40 times higher than those adopted in the *R&O* for the 5.725-5.825 GHz band.

[43] For example, Apple argues that spread spectrum devices essentially trade, in comparison to non-spread spectrum devices, lowered communications capacity for a given bandwidth in return for increased desired signal performance and multipath mitigation. Additionally, non-spread spectrum devices may have lower manufacturing costs.

to cause harmful interference to incumbent operations.[44] Additionally, ICO/Comsat argues that WINForum does not acknowledge the effect of its proposed tolerance on narrowband satellite signals. ICO/COMSAT states some satellite feeder links operate with 25 kilohertz bandwidth channels and that permitting U-NII devices effectively to double their power in certain band segments would have an even greater interference impact on narrowband satellite operations.

30. In response to opposing comments, WINForum argues that its 3-dB tolerance request will not double the potential interference created by U-NII operations to MSS feeder links because that parameter does not affect the maximum power output, but only affects how the power is distributed. WINForum claims that the allowance of a 3-dB tolerance in the PSD in any one megahertz of spectrum for U-NII operations would not impact MSS operators because of the averaging effect of the power created from a large number of devices.[45] That is, for each U-NII device that operates 3 dB over the PSD limit in a one megahertz segment, there are other U-NII devices operating in the same one megahertz segment with less power.

31. Incumbent interests also oppose Apple's change regarding PSD, arguing that it would increase the power per unit spectrum of U-NII operations and, thus, increase their potential to cause interference.[46] Specifically, NTIA argues that the purpose of making this spectrum available for unlicensed devices was to satisfy the demand for high-speed, broadband multimedia applications requiring broad channels with bandwidths up to 20 megahertz each.[47] NTIA states that Apple's request would have the undesirable effect of encouraging narrowband use of this spectrum. NTIA also argues that Apple's apparent desire to facilitate lower speed, more narrowband unlicensed communications over long distances can be achieved using unlicensed spread spectrum transmitters instead of U-NII devices. NTIA argues that specifying the PSD in terms of a two megahertz channel instead of a 20 megahertz channel would lead to an increase in the level of interference caused by U-NII devices in the 5.25-5.35 GHz and 5.725-5.825 GHz bands. Airtouch opposes an increased U-NII PSD in the 5.25-5.35 GHz band, claiming that such an increase would result in higher out-of-band emissions in the adjacent 5.15-5.25 GHz band.[48] Airtouch argues that if the Commission were to permit such an increase in PSD, then it should also decrease the permitted level of out-of-band emissions by an equal amount to protect MSS feeder links

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[44] *See* NTIA Comments at 5, Airtouch Opposition at 5, and L/Q Opposition at 8.

[45] *See* WINForum Reply at 5.

[46] We note that the incumbent parties opposed the increased PSD request in Apple's petition, however, Apple's reply comments requested an even larger increase in PSD, but commenting parties did not get a chance to respond to that request. Nevertheless, we believe any arguments made against Apple's original request would also apply to its subsequent request for increased PSD.

[47] *See* NTIA Comments at 15.

[48] *See* Airtouch Opposition at 6.

which will operate in the 5.091-5.25 GHz band.

32. In its reply comments, Apple argues that conforming the allowable PSD for U-NII devices to that allowed for unlicensed spread spectrum devices would render the interference characteristics of their various transmissions indistinguishable to an un-associated receiver.[49] Regarding Airtouch's concern that an increase in U-NII PSD would cause an increase in unwanted emissions in the 5.15-5.25 GHz band, Apple argues that in-band and unwanted emissions are not necessarily related. Apple claims that the current rules would limit unwanted emissions from U-NII devices in the middle band to levels much lower than that permitted by U-NII transmitters in the 5.15-5.25 GHz band. Therefore, Apple concludes that MSS feeder link operations would not suffer increased interference from U-NII devices in the 5.25-5.35 GHz band operating with the increased PSD proposed by Apple.

33. *Decision.* We acknowledge that there are variations in a signal's power across its emission bandwidth, but we conclude that the public interest would not be served by amending our rules to allow a 3-dB tolerance in meeting U-NII PSD requirements in any one megahertz segment, even if the total PSD requirement across the signal's bandwidth is met. However, for compliance with the PSD requirement, we will permit integration of the power over the PSD measurement bandwidth (the lesser of 1 megahertz or the 26 dB bandwidth) such that the variations in envelope power will be averaged out. For example, while WINForum's proposal would allow half of a 2 megahertz wide channel to exceed our PSD limits by 3 dB as long as the other half is 3 dB below our PSD limits, our approach would permit averaging of variations within a 1 megahertz segment, but each 1 megahertz segment must meet our PSD requirements. With this measurement procedure, we find that our current rules governing PSD requirements for U-NII devices are sufficient to accommodate the digital modulation techniques anticipated for U-NII devices. Additionally, integrating the power over the measurement bandwidth would not cause additional interference problems with other services due to the averaging effect of the power from multiple devices.

34. Regarding Apple's request concerning the PSD in the 5.25-5.35 GHz and 5.725-5.825 GHz bands, we stress that the intent of this U-NII proceeding is to facilitate broadband, high-speed unlicensed multi-media communications. We find that in amending the PSD requirements to permit the maximum power to be concentrated within a bandwidth of two megahertz instead of spread across 20 megahertz, though facilitating longer distance communications, would ultimately encourage lower speed, more narrowband communications which may not meet the future demand for high-speed multi-media applications. Additionally, increasing the permitted PSD by 167 times that adopted in the *R&O* for the 5.25-5.35 GHz band and 40 times that adopted in the *R&O* for the 5.725-5.825 GHz band, as requested by Apple's reply comments, would further discourage the use of wide bandwidth technologies. Further, the use of narrowband U-NII devices operating at maximum power could cause interference to wideband U-NII devices as they are developed. In addition,

[49] *See* Apple Reply at 4.

numerous narrowband operations could congest the spectrum and effectively block out the availability of the spectrum for the intended broadband U-NII uses.[50]

35. Further, we recognize that there is an immediate need and demand for U-NII devices to resolve wireless networking challenges, but current data rate demands may not yet be at the 20 megabit per second ("Mbit/s") level supported by the record in this proceeding. Rather than change the focus of this proceeding to the needs for slower data rate communications, we find it sufficient to permit the operation of narrowband U-NII devices at lower power. We further find that the existing U-NII PSD requirements are flexible enough to permit devices to meet current networking demands without hindering the development of future higher speed U-NII devices. Additionally, we note that narrowband unlicensed equipment is available in existing unlicensed bands to meet the current demand for communications at lower data rates. Therefore, we deny Apple's request to modify the U-NII PSD requirements to permit the spread of the maximum power across a smaller bandwidth.

36. Accordingly, we are maintaining the PSD limits adopted within the *R&O*. Specifically, U-NII devices shall limit their PSD as follows: a) in the 5.15-5.25 GHz band, the transmitter peak PSD will be limited to 2.5 mW (4 dBm) in any one megahertz band for an antenna gain of up to 6 dBi; b) in the 5.25-5.35 GHz band, the transmitter peak PSD will be limited to 12.5 mW (11 dBm) in any one megahertz band for an antenna gain of up to 6 dBi; and c) in the 5.725-5.825 GHz band, the transmitter peak PSD will be limited to 50 mW (17 dBm) in any one megahertz band for an antenna gain of up to 6 dBi (23 dBi for fixed, point-to-point systems).

C. Emission Limits.

37. *Expression of Emission Limits.* In the *R&O*, we established limits for U-NII device emissions that fall outside the bands of operation; these limits on unwanted emissions were expressed in terms relative to the operating power of the device within its emission bandwidth. In response to the *R&O*, WINForum requested clarification of the limits on unwanted U-NII emissions, suggesting that we express them in absolute terms based on the maximum permitted in-band power limits rather than in terms relative to actual in-band operating power. If the Commission were to adopt this change in how the unwanted emission limits are determined, WINForum states, manufacturers would then have the option to build less costly U-NII devices that would meet these limits by operating with less than maximum permitted power or to build full power devices that incorporate more expensive filtering. WINForum also suggests that the rules clearly state that the maximum allowed in-band PSD, which is used as a reference point for emission limits, includes the reduction in power specified in Section 15.407(a)(1-3) for devices that employ antennas with higher than 6 dBi

[50] For example, allowing full power narrowband applications might encourage a wide variety of low data rate unlicensed equipment, not necessarily networking equipment, which may ultimately congest the band and inhibit the development of future wideband applications.

gain. WINForum argues that this rule interpretation would permit the use of higher gain directional antennas on U-NII devices without causing an increase in unwanted emissions outside the U-NII bands.[51]

38. *Comments.* Comments generally support WINForum's request to express limits on unwanted U-NII device emissions in absolute terms based on the maximum permitted in-band power. Apple agrees with WINForum that emission limits should be expressed as reasonable absolute values instead of levels expressed relative to the actual transmitted in-band power.[52] NTIA agrees that stating emission limits in reference to the in-band maximum power limits will permit equipment designers to meet requirements by reducing the device's power. However, NTIA is concerned that expressing limits for U-NII unwanted emissions as an absolute level could nevertheless actually result in increased unwanted emissions if higher gain antennas are used. Specifically referring to fixed, point-to-point U-NII systems with up to 23 dBi gain antennas, NTIA adds that unwanted emissions should not be permitted to increase in conjunction with use of the additional antenna gain permitted for these operations. NTIA states that to alleviate this concern the Commission should clarify that the maximum allowed in-band PSD used as a reference point includes the specified dB-for-dB power reductions for systems with more than 6 dBi of antenna gain. In conclusion, NTIA supports WINForum's proposal for absolute emission limits provided that these limits account for appropriate power reductions for high-gain antennas.[53]

39. There is, however, one commenter that raises concerns about WINForum's proposal. In particular, Resound Corporation opposes any modification to U-NII emission limits that would allow increased interference to unlicensed operations above 5.85 GHz. Resound claims that WINForum's proposal would not limit the effect of emissions "spill-over" into bands more than 10 megahertz removed from the U-NII band edge, in contrast to the existing rules which do limit spill-over.[54] Apple responds that contrary to Resound's assertion, spill-over from the U-NII bands will be deeply suppressed under WINForum's proposed limits. Imposition of an arbitrary additional 10 dB suppression within the 25 megahertz of spectrum that lies between the U-NII upper band edge at 5.825 MHz and the lower edge, at 5.85 GHz, of Resound's unlicensed device operations, according to Apple, would amount to "technical over-kill" that would adversely affect U-NII product costs without compensatory benefit. Apple points out that low-power devices, such as Resound's, operating in the 5.850-5.875 GHz band are also unlicensed devices and thus are not entitled to protection from potential interfering operations.

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[51] *See* WINForum Petition at 10.

[52] *See* Apple Reply at 9.

[53] *See* NTIA Comments at 6.

[54] *See* Resound Comments at 2.

40. *Decision.* We conclude that expression of U-NII out-of-band and spurious emission limits as absolute radiated power levels would afford manufacturers maximum flexibility in designing U-NII devices that would comply with the emission requirements. Additionally, establishing absolute emission level limits will not result in increased interference to operations outside the U-NII bands. Therefore, as indicated below, we are revising Sections 15.407(b)(1-3) to express U-NII out-of-band and spurious emission limits in terms of the EIRP/MHz equivalents for U-NII transmitters operating at maximum permitted power with a 6 dBi gain antenna. We note that expressing U-NII emission limits in terms of EIRP/MHz does not alter the level of suppression of unwanted emission, but merely provides flexibility in meeting emission limits and expresses them in a clearer fashion. Therefore, all emissions outside the U-NII bands of operation must be suppressed accordingly. Additionally, we are revising Section 15.407(b)(3) to clarify that all emissions within 10 megahertz of the edge of the 5.725-5.825 GHz band shall not exceed an EIRP of -17 dBm/MHz, and all emissions farther than 10 megahertz from the edge of the 5.725-5.825 GHz band shall not exceed an EIRP of -27 dBm/MHz.[55] Because we are expressing the U-NII emission limits in terms of EIRP/MHz based on maximum permitted power with a 6 dBi gain antenna, we are effectively limiting the out-of-band and spurious emissions to a maximum level regardless of antenna gain. Thus, devices which utilize antennas with gains higher than 6 dBi will be required to adjust their system to meet the maximum permitted EIRP/MHz. We find that this requirement will prevent U-NII operations with high gain antennas from causing an increased level of undesirable emissions into other bands, including the spectrum above 5.85 GHz with which Resound is concerned, while permitting U-NII operations to focus the desired in-band signals to achieve longer range communications.

41. *Emission Limits in the Restricted Band.*[56] The *R&O* also stated that all U-NII devices must meet the emission requirements in the restricted bands as outlined in Section 15.205.[57] WINForum agrees that the emission limits of Section 15.205 for the restricted bands generally should apply to U-NII operations, but specifically requests that the more relaxed provisions of Section 15.407(b)(1-3) apply to those restricted bands immediately adjacent to the U-NII bands. NTIA opposes WINForum's proposal to relax the emission limits for U-NII devices in the adjacent restricted bands and supports adherence to the limits adopted in the *R&O*. Specifically, NTIA states that in the restricted bands, the more stringent general limits of Section 15.209 should supersede the emission limits set forth in Sections 15.407(b)(1-3) of the *R&O*. NTIA explains that the 4.50-5.15 GHz and 5.35-5.46 GHz bands

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[55] Manufacturers should note that the peak and average limits outlined for the restricted bands in Sections 15.205 and 15.209 continue to apply.

[56] The restricted frequency bands are those allocated for services involving safety-of-life or for services that are required by the nature of their operations to use signals received at very low received levels. Only spurious Part 15 emissions are permitted in restricted bands. *See* 47 CFR § 15.205. *See also First Report and Order*, GEN. Docket No. 87-389, 4 FCC Rcd. 3493 (1989).

[57] *See* 47 C.F.R. §§ 15.205 and 15.209.

are designated as restricted bands by Section 15.205 in order to protect sensitive Government aeronautical radionavigation operations in these bands and that WINForum's proposed emission limits in these bands would allow harmful interference to safety-of-life aeronautical operations.[58]

42. *Decision.* We clarify the rules specifying U-NII emission limits into the restricted bands but reject WINForum's contention that the U-NII emission limits of Sections 15.407(b)(1-3) should take precedence over the restricted band emission limits of Section 15.205. As reflected in Section 15.407(b)(6) adopted by the *R&O*, all U-NII emissions must meet Section 15.205 requirements for emissions into the restricted bands, in order to protect sensitive radio operations and safety-of-life radio operations. We continue to believe that these more stringent requirements are necessary and should take precedence over other more general emission limitations, but we also recognize that some clarification of our rules is warranted. For example, because the 5.15-5.25 GHz and 5.25-5.35 GHz U-NII bands are between two Section 15.205 restricted bands at 4.5-5.15 GHz and 5.35-5.46 GHz, specifying emission limits in Section 15.407(b)(1-2) within 10 megahertz of the U-NII band edges is unclear. Accordingly, we are revising Sections 15.407(b)(1-2) to clarify that they apply to emissions that emanate from U-NII devices operating in the 5.15-5.25 GHz and 5.25-5.35 GHz bands and that fall outside of the restricted bands. Specifically, for devices operating in these bands, U-NII emissions outside these bands shall not exceed an EIRP of -27 dBm/MHz.

43. *Emission Limits Below 1 GHz.* We note *sua sponte* that the *R&O* inadvertently implied that U-NII devices must *always* meet the emission limits of Section 15.209. However, we now clarify that our intent was to apply the requirements of Section 15.209 to *only those emissions that are below 1 GHz.*[59] Unaware of this, WINForum requests that we clarify that the emission limits of Section 15.209 apply to those U-NII emissions that are more than 20 megahertz outside the operating bands. In light of our clarification, however, we find that WINForum's request is moot. Accordingly, we are revising the emission requirements of Sections 15.407(b)(5) as set forth in Appendix A.

D. Clarification of the Rule Regarding Definitions and Measurement Techniques.

44. In its petition, WINForum requests that the Commission clarify certain technical definitions and compliance measurement techniques for U-NII devices so that they accurately represent the interference potential of digital wideband devices. For example, WINForum proposes definitions and measurement procedures for transmit power and peak

[58] *See* NTIA Comments at A-12. For example, NTIA states that FAA operations can have "time to alert" specifications as short as one second. Thus, interference that occurs for a fraction of a second can cause false alerts that might cause a pilot to perform unnecessary evasive actions.

[59] *See* Section 15.407(b)(5) in Appendix A of the *R&O*.

transmit power that will account for symbol-to-symbol envelope[60] variations which it claims are unimportant from the perspective of interference potential.[61] Specifically, WINForum argues that even a transmitter with a relatively constant power output can display symbol-to-symbol variations in measured power when sampled at a very high rate. WINForum argues that applying the current peak measurement techniques to digital U-NII signals will unnecessarily force U-NII devices to operate at power levels several dB below our intended power limits, without any commensurate benefit in interference reduction. Therefore, WINForum suggests new power definitions and measurement techniques that will effectively average out the short duration peaks and symbol-to-symbol envelope variations without increasing interference to other operations.[62] WINForum notes that the American National Standards Institute ("ANSI") is developing document ANSI C63.17-1998 to define parameters and measurement procedures for unlicensed Personal Communications Service ("U-PCS") devices which accounts for the characteristics of the digital modulation techniques used by U-PCS devices. It asserts that similar procedures should be adopted for U-NII devices.[63]

45. Additionally, WINForum states that some U-NII devices will operate in "burst" mode or will use power control to minimize co-channel interference. Therefore, it claims, power compliance measurements should be made over bursts that are transmitted at the maximum power control level, and any power averaging must not include time intervals during which the transmitter is off or transmitting at a reduced power level. WINForum also requests that U-NII measurement procedures distinguish between power variations due to power control and the normal symbol-to-symbol envelope power variations. WINForum suggests that to make this distinction clear, "transmitted power" should be considered to be the average symbol envelope power. WINForum argues that its proposed series of definitions and modifications will not undermine the intent of the rules and are consistent with the ANSI document ANSI C63.17-1998.

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[60] For the purposes of digital modulation, a "symbol" is a component of the signal that represents information. A certain digital modulation technique may use a specific number of symbols to convey information. A signal envelope is the boundary of a family of curves obtained by varying a parameter of a wave. Therefore, symbol-to-symbol envelope variations are changes to a signal's envelope as different information symbols are transmitted.

[61] That is, digital signals may contain some very short duration peaks that rise several dB above the constant envelope power, but the peaks are infrequent enough and short enough in duration as to not cause interference to other devices.

[62] *See* WINForum Petition at 12.

[63] For example, WINForum states that ANSI C63.17-1998 defines "transmit power" as the total energy transmitted over a time interval of at most 30 divided by B (where B is the emission bandwidth of the signal) or the "on" transmission interval time, whichever is less, divided by the interval duration. The peak transmit power is then the maximum of the transmit power, defined in this manner, over an interval of continuous transmission. WINForum argues that the choice of measurement intervals depends upon a balance between the power penalty for efficient modulation structures with symbol-to-symbol envelope variations and the need to prevent longer duration envelope peaks. WINForum also states that longer duration envelope variations that are sufficient to increase interference can be measured and controlled.

46. Further, WINForum states that using peak measurement techniques to measure PSD will overstate the interference potential of U-NII devices because of the inherent randomness of a wideband signal measured with a narrowband filter. WINForum claims that if the spectrum analyzer uses peak detection to sweep the band under measurement, the measured peak PSD will exceed the true PSD by the peak-to-average ratio of the filter output, which can be in the range of 6 to 10 dB. Therefore, WINForum proposes new definitions for PSD and peak PSD to more accurately reflect the interference potential of the device being tested.

47. WINForum requests that we establish a limit on the maximum resolution bandwidth used in measuring the emissions of U-NII devices, instead of the minimum resolution bandwidth of one megahertz in our rules. WINForum states that the effective noise bandwidth of a resolution filter in a commercial spectrum analyzer is not necessarily equal to the nominal resolution bandwidth. It claims that this difference in bandwidth can result in an inaccurate measurement of the interference potential. Additionally, WINForum argues that it is not necessary to specify a lower limit on the resolution bandwidth because the integration procedure in Section 15.407(b)(4) can be used to compute the total power over any desired bandwidth. In further support of its request, WINForum claims that for devices with narrowband emissions (*e.g.*, 100 kHz) it would not be possible to verify compliance with the limits on total output power using a one megahertz resolution bandwidth.[64] However, in contrast, WINForum asserts that a limit on the maximum resolution bandwidth is necessary to accurately isolate the power within the bandwidth of a potential victim receiver. Therefore, WINForum proposes the following definitions and measurement procedures to resolve the issues discussed above.

-15.403(b) *Peak Transmit Power.* The maximum transmit power as measured over an interval of time equal to the reciprocal of the frame rate or the transmission pulse duration of the device under all conditions of modulation. Usually this parameter is measured as a conducted emission by direct connection of a calibrated test instrument to the equipment under test. If the device cannot be connected directly, alternative techniques acceptable to the Commission may be used.
-15.403(c) *Average Symbol Envelope Power.* The average symbol envelope power is the average, taken over all symbols in the signaling alphabet, of the envelope power for each symbol.
-15.403(d) *Pulse.* A pulse is a continuous transmission of a sequence of modulation symbols, during which the average symbol envelope power is constant.
-15.403(e) *Transmit Power.* The total energy transmitted over a time interval of at most 30/B (where B is the 26 dB emission bandwidth of the signal) or the duration of the transmission pulse, whichever is less, divided by the interval duration.
-15.403(f) *Power Spectral Density.* The power spectral density is the total energy output per unit bandwidth from a pulse or sequence of pulses for which the transmit

[64] *See* WINForum Petition at 19.

power is at its peak or maximum level, divided by the total duration of the pulses. This total time does not include the time between pulses during which the transmit power is off or below its maximum level.
-15.403(g) *Peak Power Spectral Density*. The peak power spectral density is the maximum power spectral density, within the specified measurement bandwidth, within the U-NII device operating band.
-15.407(a)(5). The peak power spectral density is measured as a conducted emission by direct connection of a calibrated test instrument to the equipment under test. If the device cannot be connected directly, alternative techniques acceptable to the Commission may be used. Measurements are made over a bandwidth of 1 MHz or the 26 dB emission bandwidth of the device, whichever is less. A resolution bandwidth less than the measurement bandwidth can be used, provided that the measured power is integrated to show total power over the measurement bandwidth. If the resolution bandwidth is approximately equal to the measurement bandwidth, and much less than the emission bandwidth of the equipment under test, the measured results shall be corrected to account for any difference between the resolution bandwidth of the test instrument and its actual noise bandwidth.
-15.407(b)(4). The above emission measurements shall be performed using a maximum resolution bandwidth of 1 MHz. If a 1-MHz resolution bandwidth is used, the measured results shall be corrected to account for any difference between the resolution bandwidth of the test instrument and its actual noise bandwidth. If a resolution bandwidth less than 1 MHz is used, the measured power must be integrated to show the total power over 1 MHz. Regardless of the attenuated levels shown above, emissions outside the frequency range of operation do not need to be attenuated below the general limits in § 15.209 of this part.

48. *Comments*. NTIA acknowledges that the output of a resolution filter looks much like Gaussian noise for "well behaved" digital modulation schemes with known peak-to-average ratios, such as: BPSK,[65] QPSK,[66] QAM,[67] FSK,[68] MSK,[69] and GMSK.[70] However, it

[65] BPSK -- Binary Phase-Shift Keying -- A form of modulation in which binary data are transmitted by changing the carrier phase by 180 degrees. *See The New IEEE Standard Dictionary of Electrical and Electronics Terms, Fifth Edition*, (1993).

[66] QPSK -- Quadrature Phase-Shift Keying -- PSK modulation technique using four phase states. *See Telecommunications: Glossary of Telecommunication Terms*, Federal Standard 1037B (1991).

[67] QAM -- Quadrature Amplitude Modulation -- Quadrature modulation in which some form of amplitude modulation is used for both inputs. *Id.*

[68] FSK -- Frequency-Shift Keying -- A form of frequency modulation in which the modulating signal shifts the output frequency between predetermined values. Commonly, the instantaneous frequency is shifted between two discrete values termed the "mark" and "space" frequencies. *Id.*

argues that because the *R&O* does not limit the type of modulation technique for U-NII devices, a manufacturer could develop a modulation type that violates the peak-to-average relationship of the techniques listed above. In such cases, the peak levels could be much higher than the average levels, and, if the measurement technique is based on an average power level, then interference to Federal systems could be understated.[71] NTIA states that a possible solution would be to develop a list of modulation schemes that are permissible for U-NII devices or to specify a peak-to-average ratio to which U-NII devices must adhere. Additionally, NTIA agrees that measurements should be made over bursts that are transmitted at the maximum power control level so that power measurements accurately reflect interference potential. Any power averaging must not include time intervals during which the transmitter is off or transmitting at a reduced power level. While NTIA does not oppose the definitions proposed by WINForum, it contends that most of the definitions are related to symbol duration, but there is no proposed definition for a symbol. Accordingly, NTIA believes that WINForum's definitions can be adopted, but a definition of symbol duration should also be developed and included in the rules.

49. Additionally, NTIA agrees with WINForum that the power output of the resolution filter is noise-like when the resolution bandwidth of the spectrum analyzer is significantly less than the emission bandwidth for well-know digital modulation techniques. NTIA states that if U-NII devices were limited to using these types of digital modulation techniques, then measuring the PSD in terms of average power instead of peak power would not increase the effects of interference to Federal operations. However, unless the rules specify or limit the modulation techniques that may be employed by U-NII devices, NTIA cannot support specifying the PSD limits in terms of average power.[72]

50. *Decision.* We agree that the increasing use of advanced digital modulation techniques does warrant some reconsideration of how we define technical parameters and perform compliance measurements to ensure that equipment meets necessary technical standards. Further, we recognize that digital modulation techniques often display symbol-to-symbol envelope variations and short duration peaks that do not cause increased interference to other operations. We also note that defining power in terms of the average of all symbols in a particular modulation technique and establishing a proper time interval to measure transmission pulses would help account for the peak-to-average variations in measuring digital signals. Additionally, in order to get an accurate measurement for digital networking devices,

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[69] MSK -- Minimum Shift Keying -- A modulation technique where the tone spacing is one-half that employed for noncoherently demodulated orthogonal FSK, giving rise to the name minimum shift keying.

[70] GMSK -- Gaussian Minimum Shift Keying - MSK modulation technique where the phase trajectory is smoothed by a Gaussian low-pass filter.

[71] *See* NTIA Comments at 8.

[72] *See* NTIA Comments at 9.

we find that measurements should be made over bursts that are transmitted at the maximum power control level and that any power averaging must not include time intervals during which the transmitter is off or transmitting at a reduced power level. Further, we find that WINForum's proposed power averaging definitions would have little effect on many commonly used digital modulation techniques because they demonstrate a fairly constant envelope power. However, we are aware of the development of high data rate modulation techniques that would unjustifiably be excluded from operation in these bands without the benefit of power averaging techniques to smooth out power variations and, thus, enable devices utilizing such techniques to meet power limits.

51. Additionally, we are cognizant that measuring a wide bandwidth signal with a narrow bandwidth filter causes some inherent randomness in the results. The peak detection setting of a spectrum analyzer as it sweeps a wide bandwidth signal may display a PSD that exceeds the true PSD by the peak-to-average ratio of the filter output. While we agree with NTIA that there is no way to predict what types of modulation technologies will be developed in the future, rather than preclude the use of future modulation techniques that may benefit U-NII operations, we shall impose a 13 dB limit on the ratio between the peak excursion of the modulation envelope (measured using a peak hold function) and the peak transmit power (measured as specified above) across the lesser of any 1 MHz bandwidth or the emission bandwidth. Additionally, we will require measurements to be made using the procedures specified in our rules and in document ANSI C63.17-1998 over an interval of continuous transmission during which the output power is at a maximum. We conclude that this approach will enable the development of new U-NII digital modulation techniques that will not have an undesirably high potential for causing interference to other devices and services.

52. Regarding the measurement of unwanted emissions, we reaffirm our finding in the *R&O* that these measurements should be performed with a minimum resolution bandwidth of one megahertz. We note that Section 15.35(b) of our rules requires that a minimum resolution bandwidth of one megahertz be used to measure unwanted emissions for all unlicensed Part 15 devices operating above 1 GHz.[73] By using a minimum resolution bandwidth, we reduce the influence of different filter responses and ensure repeatability of measurements. Nevertheless, we will permit a lower resolution bandwidth for measurements near the band edge, when necessary, provided the measured energy is integrated to show the total power over one megahertz. Therefore, we find that WINForum's proposed definitions for "average symbol envelope power," "pulse," "transmit power," "peak transmit power," "power spectral density," and "peak power spectral density" combined with the use of measurement techniques specified in our rules and in ANSI C63.17-1998 are appropriate and will permit accurate measurement of U-NII technical parameters. Additionally, we find that adoption of these definitions will resolve the issues discussed above without increasing interference from U-NII devices. Accordingly, we modify Sections 15.403, 15.407(a)(5) and

[73] *See* 47 C.F.R. §15.35(b).

15.407(b)(4) to read as indicated in Appendix A below.[74]

E. U-NII Modulation Techniques.

53. In the *R&O*, we defined U-NII devices as intentional radiators operating in the 5.15-5.35 GHz and 5.725-5.825 GHz bands that provide a wide array of wideband, high data rate, digital, mobile and fixed communications for individuals, businesses, and institutions. In its petition, WINForum argues that the intent of this proceeding was to foster the development of advanced wideband digital radio technologies for applications requiring high data rates. Therefore, to minimize unintended use of this spectrum, WINForum requests that the definition of U-NII devices be modified to permit use of only digital modulation techniques by U-NII devices. Specifically, WINForum's proposed definition reads as follows:

> Section 15.403(a) U-NII devices [Unlicensed]. Intentional radiators operating in the frequency bands 5.15-5.35 GHz and 5.725-5.825 GHz that use wideband digital modulation techniques and provide a wide array of high rate mobile and fixed communications for individuals, businesses, and institutions.

54. Additionally, WINForum suggests that the U-NII rules permit devices that use impulse modulation techniques. WINForum argues that special rule considerations are necessary for very short duration "impulse" transmission techniques[75] because extremely wideband signals of short duration cannot accurately be measured with conventional spectrum analyzers due to limitations in the response time of the resolution filters. WINForum states that it will discuss impulse measurement techniques with NTIA to develop a procedure for measuring power output and PSD of impulse transmissions, which will be recommended to the Commission. WINForum states that it will be necessary for a Part 15 Certification applicant to disclose details such as modulation format, minimum pulse duration, minimum and maximum pulse repetition rate, spectral characteristics under expected conditions of operation, etc., so that the Commission can apply the appropriate test procedures.

55. *Comments*. NTIA supports specifying the types of modulation that will be permitted in the definition for U-NII devices because it would help the development of future Government systems in the bands by defining the interference environment. Additionally, NTIA argues that it may help to adopt a minimum bandwidth in the definition to preserve the true purpose of opening these bands to U-NII operations, which it argues is to open spectrum for unlicensed broadband data applications that cannot be supported by current unlicensed spectrum.

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[74] We note that the definitions adopted by this action, in Appendix A, contain minor modifications to those proposed by WINForum which either add clarity or removes unnecessary language.

[75] Impulse transmission systems are characterized by a wide bandwidth and extremely high peak power levels of a short duration.