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

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Federal Communications Commission
Office of Secretary

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

WIRELESS INFORMATION NETWORKS FORUM
PETITION FOR RECONSIDERATION AND CLARIFICATION

WIRELESS INFORMATION
NETWORKS FORUM

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SUMMARY

As one of the original petitioners seeking 5 GHz spectrum for unlicensed multimedia products, WINForum commends the Commission for its prompt action to adopt the U-NII Order. This order allocates three bands of 100 MHz each near 5 GHz and establishes minimal technical rules designed to ensure the broadest range of technologies and equipment and the optimal compatibility between U-NII devices and other spectrum users. While, in large part, WINForum strongly supports the Commission's order, WINForum's technical committees have extensively studied the regulations and have noted a number of areas where clarifications or minor modifications would be in the public interest. As discussed below, WINForum believes adoption of these clarifications and modifications would be consistent with the intent of the Commission's rules.

First, WINForum urges the Commission to clarify that operation across the lower and middle band boundary at 5.25 GHz is permissible. As discussed in the petition, the spectrum in the lowest 100 MHz (5.15-5.25 GHz) is immediately adjacent to the middle band (5.25-5.35 GHz), but subject to more stringent power and operational requirements. Nonetheless, if the regulations for the lowest band are met, there appears to be no reason to constrain U-NII devices from operating using channels that cross the 5.25 GHz boundary.

Second, WINForum believes the Commission should clarify and harmonize the out-of-band emissions limitations with the general "quiet band" limits of Section 15.209. In this petition, WINForum suggests extending the specific Section 15.407 out-of-band emissions limits from 10 MHz to 20 MHz from the band edges, and then applying the Section 15.209 quiet band limits beyond that point. WINForum has initiated discussions with NTIA, as manager of the

spectrum immediately above and below the U-NII bands, specifically considering the potential ramifications of the proposed clarifications. These discussions, however, are not yet complete. WINForum will continue to work with NTIA on these specific issues and apprise the Commission if such discussions require modification of the positions stated herein.

Third, WINForum argues that the Commission should eliminate the frequency stability requirements, since no band channelization has been adopted. With the existing out-of-band emission limits, all adjacent channel protection requirements are already inherent in the rules and frequency stability rules are unnecessary.

Fourth, WINForum urges the Commission to revise the output power and power spectral density rules to avoid disadvantaging broadband systems. Under the current rules, systems with a bandwidth of less than 1 MHz could be deployed and utilize the same power allowed for systems of 1 MHz, gaining a signal-to-noise advantage. Instead, WINForum suggests that the total power be specified as X dBm + 10logB, where B is the 26 dB bandwidth in MHz and X is 4 dBm for the 5.15-5.25 GHz band, 11 dBm for the 5.25-5.35 GHz band, and 17 dBm for the 5.725-5.825 GHz band. WINForum also suggests allowing 3 dB of tolerance in any given 1 MHz band, while maintaining the total power output as a function of bandwidth (as specified above), in recognition that most modulation envelopes are not "spectrally flat."

Fifth, WINForum believes the Commission should state the out-of-band emission limits relative to the in-band power limits, including the required power reduction for systems with more than 6 dBi of antenna gain, rather than as relative to actual transmitted in-band power. By stating the out-of-band emission limit as a function of the maximum permitted in-band power, rather than as a function of actual in-band power, equipment designers will be able to utilize in-band power reduction to meet the out-of-band limitations. This added flexibility could reduce

the cost of certain types of equipment for the band, but ultimately would not alter the magnitude of the power transmitted into adjacent bands.

Sixth, the Commission should clarify and modify the rules to specify the total power output in a manner that accurately represents the interference potential of U-NII devices. As detailed in the petition, symbol-to-symbol envelope variations due to modulation are unimportant from the perspective of interference potential. Accordingly, WINForum proposes a series of definitions and modifications, consistent with the trend taken by ANSI C63.17 for unlicensed personal communications devices, that compensates for short term envelope variations without undermining the intent of the rules.

Seventh, WINForum urges the Commission to clarify the definition and measurement of power spectral density and peak power spectral density. As detailed extensively in two attached papers, experimental and theoretical research demonstrates that using peak measurement techniques will significantly overstate the interference potential of U-NII devices due to the inherent randomness of a wideband signal measured with a narrowband filter. WINForum therefore proposes definitions and measurement techniques that it believes accurately and correctly represent the interference potential of U-NII devices and retain consistency with the intent of the Commission's rules.

Eighth, above and beyond the measurement issues described above, WINForum notes that special rules considerations are necessary for impulse transmissions techniques. Because extremely wideband signals of short duration (e.g., 10 ns) cannot accurately be measured with conventional spectrum analyzers due to limitations in the response time of the resolution filters, some special treatment under the rules is required if these devices are to be permitted.

WINForum is working in conjunction with NTIA to develop techniques for accurately representing the interference potential of these devices.

Finally, WINForum urges the Commission to modify the definition of U-NII devices to require such devices to utilize digital modulation techniques. At present, the rules require digital communications, which WINForum believes was intended to foster the development of advanced wideband digital radio technologies. In furtherance of this intent, WINForum urges the Commission to modify section 15.403(a) to require U-NII devices to employ digital modulation.

WINForum believes that the rule clarifications and changes suggested above will enhance the utility of the U-NII bands without altering the interference potential of U-NII devices. The proposed modifications thus are fully consistent with the Commission's intent and should be adopted in the public interest.

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WIRELESS INFORMATION NETWORKS FORUM
PETITION FOR RECONSIDERATION AND CLARIFICATION

The Wireless Information Networks Forum ("WINForum") hereby respectfully requests the Commission to reconsider and clarify aspects of the recently adopted Report and Order in the above-captioned proceeding.[1] As one of the original proponents of an allocation in the 5 GHz band for unlicensed NII ("U-NII") devices, WINForum strongly commends the Commission for its expeditious action to make spectrum available for multimedia systems on an unlicensed basis. WINForum believes the Commission's leadership will realize tremendous benefits domestically -- and internationally -- for students, medical care providers, businesses, industries, and consumers generally. In a few respects, however, the technical regulations adopted in the *U-NII Order* may unnecessarily restrict design flexibility and thereby impair the capabilities of these devices. In order to assure the greatest variety of functional U-NII products, WINForum therefore requests the Commission to clarify and reconsider certain technical regulations, as discussed in further detail below.

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[1] Amendment of the Commission's Rules to Provide for Operation of Unlicensed NII Devices in the 5 GHz Frequency Range, ET Docket No. 96-102, RM-8648, RM-8653 (Jan. 9, 1997) ("*U-NII Order*"). See also 62 Fed. Reg. 4649 (Jan. 31, 1997). Under Section 1.429(d) of the Commission's Rules, petitions for reconsideration are therefore due on March 3, 1997.

I. INTRODUCTION

On May 15, 1995, WINForum filed a petition for rulemaking seeking allocation of spectrum in the 5 GHz band for unlicensed products supporting wideband, high-speed multimedia applications.[2] WINForum's petition, and a similar but independent petition filed by Apple Computer, Inc. on May 24, 1995 were placed on public notice on June 7, 1995,[3] and, based on significant public support, a notice of proposed rulemaking was issued on May 6, 1996.[4] Now, in only one and half years since the original petitions were filed, the Commission released the *U-NII Order* allocating 300 MHz of spectrum in the 5 GHz band for multimedia networking applications. WINForum strongly commends the Commission's recognition of the extreme potential impact of multimedia technologies and for its recognition of the power that untethering these technologies may have on future generations of computer users.

As requested by WINForum and Apple, the *U-NII Order* allocates a substantial amount of spectrum in the 5 GHz band for new unlicensed technologies. The *U-NII Order* allocates three bands of 100 MHz each – 5.15-5.25 GHz, 5.25-5.35 GHz, and 5.725-5.825 GHz – each with distinct power limits. In most respects, however, only minimal technical regulations have been adopted to protect against interference with co-channel and adjacent channel services. For example, while no minimum channelization has been adopted for the band, the Commission has

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[2] WINForum Petition for Rulemaking, RM-8648 (filed May 15, 1995).

[3] Apple Computer, Inc. Petition for Rulemaking, RM-8653 (filed May 24, 1995); Extension of Time for Comments, 11 FCC Rcd 5410 (1995) (consolidating pleading cycles on petitions).

[4] Amendment of the Commission's Rules to Provide for Operation of Unlicensed NII/SUPERNet Devices in the 5 GHz Frequency Range, 11 FCC Rcd 7205 (1995).

imposed power spectral density limits that encourage nominal channel sizes of approximately 20 MHz.

WINForum also notes that, unlike the 2 GHz unlicensed personal communications service ("UPCS") allocation, no "spectrum etiquette" has been adopted for the 5 GHz band to govern access to and use of U-NII spectrum. Specifically, the Commission found that the drawbacks of an etiquette in the 5 GHz band include "an increase the complexity of equipment design and, hence, an increase in cost to the manufacturer and the user, as well as a potential limitation on access to the spectrum by some technologies and equipment."[5] At the same time, the Commission noted that "an etiquette could beneficially facilitate compatibility among devices and thus promote spectrum sharing, intercommunications among different devices, and equal access to the spectrum by devices built by various manufacturers."[6] The Commission also observed that "[i]f standards are developed that would better facilitate sharing of this band without precluding U-NII devices or technologies," that it would "consider adopting those protocols in a further rulemaking proceeding."[7] The Commission further recognized the efforts of WINForum to develop equitable sharing rules for the band, and "encourage[d] all interested parties to take part in this process and to cooperate in good faith."[8]

WINForum continues to believe that sharing rules can be structured in a manner that allow more equitable sharing of spectrum resources and increased spectral efficiency without

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[5] *U-NII Order* at ¶ 70.

[6] *Id.* at ¶ 71.

[7] *Id.*

[8] *Id.*

constraining innovative technology. WINForum's Sharing Rules Drafting Committee ("SRDC") is continuing to move ahead with development of sharing rules for the band, and encourages participation by interested manufacturers. WINForum's SRDC will continue to apprise the Commission of its progress as rules are developed.

II. DISCUSSION

WINForum believes the framework for the use of the 5 GHz band by U-NII devices represents in most respects a practical, if somewhat conservative, compromise between the needs of unlicensed technologies and other services sharing the spectrum. In a few limited areas, however, the technical limitations in the rules are unclear and may be misinterpreted in an unnecessarily restrictive manner. Specifically, WINForum requests that the Commission:

A. Clarify that devices may operate using channels that overlap between the lower (5.15-5.25 GHz) and middle (5.25-5.35 GHz) bands, as long as such devices adhere to the more restrictive lower band technical limits;

B. Clarify and harmonize the out-of-band emission limits in Section 15.407(b) with the general limits of Section 15.209;

C. Delete the frequency stability requirement set forth as new Section 15.407(g), which is unnecessary absent channelization of the U-NII spectrum;

D. Modify the output power and power spectral density rules to avoid advantaging narrowband systems;

E. Modify the Rules to state the out-of-band emissions limitations absolutely rather than as relative to in-band power;

F. Specify the total power output in a manner that accurately represents the interference potential of U-NII devices;

G. Clarify the definition and measurement of power spectral density and peak power spectral density;

H. Modify the Rules to control the power output of very short duration "impulse" emissions; and,

I. Clarify the definition of U-NII devices to require digital modulation.

Each of these points is detailed briefly below.

A. U-NII Devices Should Be Permitted To Operate Across the 5.25 GHz Boundary Subject to the Lower Band Operating Rules

The Commission should clarify that U-NII devices can be developed that utilize a channel pattern overlapping the boundary between the lower and middle bands. For example, there appears to be no reason to prohibit a device from utilizing a 50 MHz channel that spans from 5.225-5.275 GHz. Indeed, the existence of such devices appears to be contemplated under the Commission's rules, which specify an out-of-band emissions limit for devices in the lower band that does not commence until 5.35 GHz. In any case where a device channel spans the lower/middle band boundary at 5.25 GHz, the device would be required to meet the more restrictive lower band power limits and indoor only operating condition. Subject to that restriction, however, the Commission should clarify that operation across the lower and middle frequency bands is permissible.

B. The Out-of-Band Emission Limits in Section 15.407(b) Should be Clarified and Harmonized With the General Limits of Section 15.209

The out-of-band emission limits in Section 15.407(b), if interpreted as attenuation levels relative to the maximum allowed in-band power spectral density as proposed above, would require that the emissions in the 10 MHz immediately adjacent to a U-NII band be no more than –23 dBm/MHz. Beyond that 10 MHz "shoulder", the limit becomes –33 dBm/MHz. The point at which the emissions are required to comply with the limits of Section 15.209 is not specified.

WINForum proposes that the –33 dBm/MHz level be maintained for another 10 MHz, beyond which the limits of Section 15.209 would apply. For frequencies above 1 GHz, that limit is 500 μV/m measured at 3 meters, which equates to –41.2 dBm EIRP, measured as a 100 millisecond average with a 1-MHz measurement bandwidth. The peak must be no more than 20 dB above this, or –21.2 dBm EIRP.

With this proposal, Section 15.407(b)(1-3) would become:

> (1) For transmitters operating in the band 5.15-5.25 GHz: all emissions within the frequency range 5.14-5.15 GHz and 5.35-5.36 GHz must be attenuated by a factor of at least 27 dB; all emissions within the frequency range 5.13-5.14 GHz and 5.36-5.37 GHz must be attenuated by a factor of at least 37 dB; all emissions below 5.13 GHz and above 5.37 GHz must comply with the general limits of §15.209.
>
> (2) For transmitters operating in the band 5.25-5.35 GHz: all emissions within the frequency range from the band edge to 10 MHz outside the band edge must be attenuated by a factor of at least 34 dB; all emissions within the frequency range from 10 MHz outside the band edge to 20 MHz outside the band edge must be attenuated by a factor of at least 44 dB; all emissions more than 20 MHz outside the band edge must comply with the general limits of §15.209.
>
> (3) For transmitters operating in the band 5.725-5.825 GHz: all emissions within the frequency range from the band edge to 10 MHz outside the band edge must be attenuated by a factor of at least 40 dB; all emissions more than 10 MHz outside the band edge must be attenuated by a factor of at least 50 dB.

With these changes, the first sentence in Section 15.407(b)(5) can be eliminated, so that Section 15.407(b)(5) would become:

> (5) Any U-NII devices using an AC power line are required to comply also with the conducted limits set forth in Section 15.207.

Finally, to be consistent with the above, Section 15.407(b)(6) would become:

> (6) The provisions of §15.205 of this part apply to intentional radiators operating under this section, except as specified in (1)-(3) above.

WINForum has initiated discussions with NTIA, as manager of the spectrum immediately above and below the U-NII bands, specifically considering the potential ramifications of the proposed clarifications. These discussions, however, are not yet complete. WINForum will continue to work with NTIA on these specific issues and apprise the Commission if such discussions require modification of the positions stated herein.

C. The Frequency Stability Requirements Should Be Deleted As Unnecessary Because No Channelization Has Been Mandated

Section 14.407(g) should be deleted as unnecessary. This section specifies limitations on the variability of the carrier frequency of a device. However, carrier frequency stability is only relevant for channelized systems where devices with imprecise carrier frequency tolerances could drift into other channels or otherwise cause adjacent channel interference.[9] Because the Commission has declined to adopt a channelization scheme for the band, no carrier frequency stability is needed and the section should therefore be deleted.

D. The Output Power and Power Spectral Density Rules Should Not Advantage Narrowband Systems

WINForum understands that the Commission's intent in formulating the new Rules for U-NII devices was to encourage the development of wideband unlicensed wireless systems. The

[9] WINForum notes that, even in the absence of carrier frequency stability requirements, the out-of-band emissions limitations govern any potential interference to services in adjacent allocations.

effect of the power spectral density limits in Section 15.407(a)(1-3) is to allow a total power output that is proportional to the emission bandwidth, up to the specified limit on the total power output. This means that in principle, wideband devices operate on an even footing with narrowband devices, with respect to signal-to-noise ratio, since the noise floor is also proportional to bandwidth.

This equitable intent can be undermined by the fact that Section 15.407(a)(5) specifies that measurements are to be made with a 1 MHz resolution bandwidth. The implication is that a device with an emission bandwidth less than 1 MHz would be allowed the same total power output as a device with a 1-MHz bandwidth, thus gaining a signal-to-noise advantage. Moreover, a number of such narrowband devices could be "clustered" in a small region of the spectrum, thus generating more interference than a single device with a bandwidth of 1 MHz or greater.

As a solution to this problem, WINForum proposes that the total power output be specified as X dBm + 10logB, where B is the 26-dB bandwidth in MHz and X is 4 dBm for the 5150-5250 MHz band, 11 dBm for the 5250-5350 MHz band, and 17 dBm for the 5725-5825 MHz band. The maximum power output levels would be the same as those specified in Section 15.407(a)(1-3).

In addition, WINForum proposes that allowance be made for the fact that most signals are not spectrally "flat", but rather exhibit some degree of variability in the power spectral density across their emission band. This could be accommodated by allowing a 3-dB tolerance in any given 1-MHz band, while maintaining the total power output as a function of bandwidth as specified above.

With these modifications, Section 15.407(a)(1-3) would be:

(1) For the band 5.15-5.25 GHz, the peak transmit power over the frequency band of operation shall not exceed the lesser of 50 mW or 4 dBm + 10logB, where B is the 26-dB emission bandwidth in MHz. In addition, the peak power spectral density shall not exceed 7 dBm in any 1-MHz band. If transmitting antennas of directional gain greater than 6 dBi are used, both the peak transmit power and peak power spectral density shall be reduced by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

(2) For the band 5.25-5.35 GHz, the peak transmit power over the frequency band of operation shall not exceed the lesser of 250 mW or 11 dBm + 10logB, where B is the 26-dB emission bandwidth in MHz. In addition, the peak power spectral density shall not exceed 14 dBm in any 1-MHz band. If transmitting antennas of directional gain greater than 6 dBi are used, both the peak transmit power and peak power spectral density shall be reduced by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

(3) For the band 5.725-5.825 GHz, the peak transmit power over the frequency band of operation shall not exceed the lesser of 1 W or 17 dBm + 10logB, where B is the 26-dB emission bandwidth in MHz. In addition, the peak power spectral density shall not exceed 20 dBm in any 1-MHz band. If transmitting antennas of directional gain greater than 6 dBi are used, both the peak transmit power and peak power spectral density shall be reduced by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

Not only would these limits eliminate the "loophole" for narrowband devices in the existing Rules, but they would effectively limit availability of the 3-dB tolerance to devices with bandwidths exceeding 1 MHz, providing a mild incentive to use wideband modulation.

E. The Out-of-Band Limits Should Be Stated Relative To In-Band Limits Rather than Actual In-Band Power

The Commission should revise the out-of-band emissions limitations to allow devices to meet the specifications by lowering their output power. Under the current rules, if a device cannot meet the out-of-band emissions limitations, reduction of power is not an option, since

attenuation from the "maximum peak power spectral density contained within the band of operation" is required. Thus, if a particular U-NII device has an emission mask that exceeds an out-of-band emissions attenuation limit by only 2 dB, the power cannot be reduced 2 dB to compensate, but instead more filtering will be required. However, very sharp emissions filters can increase the cost of unlicensed devices significantly. Thus, despite that there is no difference in the level of unwanted emissions between the options facing the manufacturer, the rules currently force the device designer to opt for the more expensive method of meeting the specifications even if, for that particular application, the allowed power may be in excess of what is absolutely necessary. Instead, WINForum suggests that the out-of-band emissions rules be modified to reference the maximum permitted in-band power level for such a device.

WINForum understands that the existing rules in Section 15.407(b)(1-3) reflect concerns that absolute levels for out-of-band emission limits could result in high out-of-band effective isotropic radiated power (EIRP) if a high-gain antenna is used. However, if it is made clear that the "maximum allowed" in-band power spectral density, which is used as a reference point, includes the reduction specified in Section 15.407(a)(1-3), then the EIRP for the out-of-band emissions will be limited in the same manner as the in-band emissions. Accordingly, WINForum requests that Section 15.407(b) be modified to read:

(b) The emissions outside of the frequency band of operation shall be attenuated below the maximum power spectral density allowed within the band of operation, including the reduction specified in Paragraph (a) above for antennas with gain exceeding 6 dBi, but not including the 3-dB tolerance for power spectral density, in accordance with the following limits:

F. The Commission Should Specify the Total Power Output in a Manner that Accurately Represents the Interference Potential of U-NII Devices

WINForum urges the Commission to specify the power output of U-NII transmitters in a manner that is independent of symbol-to-symbol envelope variations and which neither understates nor overstates the actual power of the device from the perspective of its interference potential. As recognized by ANSI C63.17 for unlicensed PCS devices, 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. For this reason, ANSI C63.17 defines "transmit power" as "the total energy transmitted over a time interval of at most 30/B (where B is the emission bandwidth of the signal), 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. The ANSI definition is consistent with the overall aim of controlling the interference potential of compliant devices without compromising the value of advanced digital modulation techniques that may be used to optimize spectrum utilization.

The RF power level is, of necessity, measured over some time interval. The peak envelope power is the power measured over the maximum amplitude cycle of the signal, while the average power is normally measured "during an interval of time that is long compared to the lowest frequency encountered in the modulation taken under normal conditions." (The definitions are paraphrased from ITU definitions 151 and 152). Peak power for digitally modulated signals should be defined over an interval of length somewhere between these extremes.

It is expected that the duration of transmissions of U-NII devices will usually exceed 20 symbol times. However, shorter duration transmissions conceivably could occur. For this reason,

WINForum proposes the power measurement interval be the transmission duration when this duration is less than 30/B. This will prevent extremely short duration emissions of very high power.

There is justification for setting the interval for a U-NII device at 30/B or approximately 20 digital symbol times for transmission times that exceed 30/B:[10]

First, efficient modulation techniques have envelope variations that occur over time intervals related to the digital symbol duration. Averaging the envelope variations over a few symbol times permits these techniques without serious penalty. Thus, overall spectrum efficiency gains are possible if envelope variations over the proposed 30/B interval are permitted.

Second, the interference potential of a wideband digitally modulated signal is related to the level over a longer sustained time than a single carrier cycle. When the potential victim receiver has a narrow bandwidth relative to that of the interfering signal, symbol-to-symbol envelope variations of the wideband signal will occur at too high a rate to be "seen" by the narrowband receiver. In fact, the received signal will have a non uniform envelope regardless of the wideband signal envelope symbol-to-symbol variations. Further, the envelope variations of the signal seen by the narrowband receiver generally will be much larger than those of the overall wideband signal. A detailed explanation of this phenomenon is provided in Attachment A. That attachment also provides experimental results, which show that for a signal with an overall 3-dB peak-to-average envelope power ratio, the peak-to-average ratio seen by a narrowband filter approaches 8 dB. Further, the delay spread normally encountered in the U-NII environment will cause an otherwise constant envelope signal to have a variable envelope at the point of

[10] It is assumed that the bandwidth is 1.5 divided by the symbol duration.

interference in a wideband receiver. Finally, in an interference limited environment, the composite interference will consist of a number of interfering signals and thus have a variable envelope. For these reasons it is unnecessary to control the power over a single cycle in order to control the interference potential.

The correct choice of measurement interval 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. Attachment B presents an analysis of the potential interference increase due to power envelope variations that are slow relative to the digital symbol time and shows that such variations of sufficient duration to increase interference potential can be measured and controlled.

WINForum expects that many U-NII devices will transmit in the "burst" mode rather than continuously. Moreover, some U-NII devices may use power control to minimize co-channel interference and maximize battery life. For power measurements to accurately reflect interference potential, it is important that the measurements be made over bursts that are transmitted at the maximum power control level. Any averaging must *not* include time intervals during which the transmitter is off or transmitting at a reduced power level, so it is important to distinguish between power variations due to power control, and the normal symbol-to-symbol envelope power variations.

To make this distinction clear, WINForum believes that a useful way to view the "transmitted power" is by the average symbol envelope power. Each symbol in the signal alphabet has an associated envelope power level, relative to an arbitrarily-selected reference symbol. The "transmitted power" is the average, over the symbol alphabet, of these relative levels, multiplied by the power level of the reference symbol. A "pulse" is then a continuous

transmission of successive symbols during which the average symbol envelope power is constant; that is, when there are no power control variations. The PSD must be measured as an average over pulses during which the average symbol envelope power is at its maximum level.

WINForum therefore requests that the Commission adopt the additional definitions as follows:

> **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.

With this definition of a "pulse", the "transmit power" can be defined in terms that relate to the manner in which it is measured, as follows:

> **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.

WINForum also proposes that the definition of Peak Transmit Power be modified editorially. The following change preserves the meaning but is preferred.

> **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.

These modifications will permit accurate measurement of the true interference potential of a U-NII device, in accordance with the Commission's overall intent. In some cases, it may be

necessary for the manufacturer to provide for a test mode which deactivates any power control and allows the device to transmit pulses with the maximum average symbol envelope power.

G. The Commission Should Clarify the Definition and Measurement of Power Spectral Density and Peak Power Spectral Density

The power spectral density ("PSD") of a continuous transmission is the average transmitted power per Hz at a particular frequency. PSD is normally measured with a spectrum analyzer, using a resolution bandwidth ("RBW") that is much less than the emission bandwidth of the equipment under test. To measure PSD, the spectrum analyzer effectively sweeps a "resolution filter" (with bandwidth RBW) across the signal bandwidth. The magnitude of the trace on the analyzer display is determined by the power output of the resolution filter.

As demonstrated in Attachments A and B, both theoretically and with experimental results, the power output of the resolution filter is noise-like when the RBW is significantly less than the emission bandwidth. It is shown in Attachment A that as the ratio of the RBW to the emission bandwidth decreases, the probability distribution of the resolution filter power output approaches that of Gaussian noise. As a result, the resolution filter power output is highly variable and exhibits a large peak-to-average ratio.[11] However, as is mathematically proven in Attachment A, the average (or in statistical terms, the "expected value") of the filter power output is the actual PSD at the filter center frequency multiplied by the noise bandwidth (or "impulse bandwidth") of the resolution filter. Therefore, to determine the actual PSD, the power

[11] This noise-like property of the resolution filter output accounts for the commonly-observed "rough" appearance of the single-sweep spectrum analyzer trace of the signal spectrum. It is also the reason that a wideband signal (such as a direct-sequence spread spectrum signal) appears as Gaussian noise to a narrowband receiver.

output of the resolution filter must be time-averaged. If instead, the spectrum analyzer's peak detection or "max hold" mode is invoked, the measured PSD will exceed the true PSD by the peak-to-average ratio of the filter output, which can be in the range of approximately 6 to 10 dB.[12] The effect will be to penalize the device under test by that amount.

The use of peak detection for measuring PSD has two other undesirable effects. First, it favors devices with emission bandwidths on the order of 1 MHz, if a 1-MHz resolution filter is used. Since all of the power of the 1-MHz device will fall within the bandwidth of the resolution filter, the peak-to-average ratio of the filter output for the 1-MHz device will be limited to the actual peak-to-average ratio of the modulation, which typically is much lower than for the noise-like filter output that results from a wideband input to the filter. Second, for a wideband (*e.g.*, 20 MHz bandwidth) emission, it may be necessary to compute the total power output by integrating the power measured with a resolution bandwidth that is much less than the emission bandwidth of the device, since the maximum resolution bandwidth of most commercial spectrum analyzers is 2 to 3 MHz. If peak detection is used, the total computed power output would be 6 to 10 dB greater than the actual power output. Again, the effect would be to penalize the U-NII device by this amount. As an example, a 10-dB penalty would in effect reduce the limits on total power output to 5 mW in the 5150-5250 MHz band, 25 mW in the 5250-5350 MHz band, and 100 mW in the 5725-5825 MHz band. The result would be to reduce the service area, under free-space conditions, by 90 percent.

[12] The exact peak-to-average ratio will depend on the specific resolution filter shape, the baseband shaping of the modulating waveform, the randomness of the modulating signal, etc.

From an interference perspective, it is the true PSD, rather than the peak power output of a 1-MHz resolution filter, which should be limited, because it is the true PSD over the "victim" receiver bandwidth that will determine the effect of the interference on the victim receiver. As is well-known, receiver performance is generally characterized in terms of the bit error rate versus the ratio of the average "desired" signal power to the average noise power. The bit error rate is normally computed assuming Gaussian noise. Therefore, since the power from a wideband U-NII device into a narrowband receiver (*e.g.,* with a bandwidth of 1 MHz or less) will appear as Gaussian noise, it is the average power of the U-NII emission within the victim receiver bandwidth that is important.[13]

As with measurements of total power, it is important that the measurements be made over pulses that are transmitted at the maximum power control level. The averaging described above, which is necessary to determine the actual PSD, must *not* include time intervals during which the transmitter is off or transmitting at a reduced power level. That is, the averaging must be performed over pulses during which the average symbol envelope power, as defined in the proposed definition above, is at its maximum level.

To clarify the measurement of PSD, WINForum therefore requests that the Commission adopt the additional definitions as follows:

> **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 power is at its peak or maximum level, divided by the total duration of the pulses. This total time

[13] The variability of the interference power from the U-NII device into the victim receiver will generally be somewhat less than that of Gaussian noise, and the effect of the U-NII emissions on the victim receiver will be somewhat less severe than that of Gaussian noise with the same power. True Gaussian noise represents a worst-case.

> 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, with the specified measurement bandwidth, within the U-NII device operating band.

Clarification also is needed regarding the measurement bandwidth for PSD. Section 15.407(a)(5) states, for the in-band PSD, that "[m]easurements are made using a resolution bandwidth of 1 MHz." For the out-of-band PSD, Section 15.407(b)(4) states: "[t]he above emission measurements shall be performed using a minimum resolution bandwidth of 1 MHz. A lower resolution bandwidth may be employed near the band edge, when necessary, provided the measured energy is integrated to show the total power over 1 MHz."

WINForum notes that the effective noise bandwidth, or impulse bandwidth, of resolution filters in commercial spectrum analyzers are not necessarily equal to the nominal resolution bandwidth. For example, for the analyzer used in the experiments described in Attachment A, the actual noise bandwidth is about 1.6 times the RBW, according to the instrument's documentation. The average power output of the resolution filter therefore will be about 2 dB above the actual PSD in dBm per MHz. Accordingly, a correction factor needs to be applied to the measured results to account for the actual noise bandwidth of the resolution filter. Otherwise, the measured result will not accurately reflect the interference potential over the bandwidth of interest.

In general, WINForum does not believe that it is necessary to specify a lower limit on the resolution bandwidth, only an upper limit. The integration procedure noted in Section 15.407(b)(4) can in principle be used to compute the total power over any desired bandwidth. In fact, such a procedure may be necessary to measure the total power output of a wideband emission, since the maximum resolution bandwidth of commercial spectrum analyzers is

typically 2 or 3 MHz. Moreover, for devices with narrowband emissions (*e.g.*, 100 kHz), it would not be possible to verify compliance with the modified limit on total output power proposed above using a 1-MHz resolution bandwidth. A limit on the *maximum* resolution bandwidth clearly is necessary in order to accurately isolate the power within the bandwidth of a potential victim receiver.

In light of these factors, WINForum proposes that Section 15.407(a)(5) and (b)(4) be modified to read as follows:

> **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 attenuation 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.