Report and Recommendations of the MILLIMETER WAVE COMMUNICATIONS WORKING GROUP to the FEDERAL COMMUNICATIONS COMMISSION

December 13, 1996

Members:

Apple Computer
Eaton Division of Cutler-Hammer
Hewlett-Packard Laboratories
Hughes Research Laboratories
Metricom
Motorola
Rockwell International
Sun Microsystems

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I. About the Working Group

In its First Report and Order and Second Notice of Proposed Rulemaking in ET Docket No. 94-124 (the "First R&O/Second NPRM"), the Federal Communications Commission (the "Commission") established a general unlicensed band at 59-64 GHz. In order to maximize the effectiveness of the band, the Commission also proposed to permit industry to develop a "spectrum etiquette" to minimize interference in this band and delayed implementation of the rules permitting unlicensed use of the band for one year to give industry time to develop a set of recommendations.

The Millimeter Wave Communications Working Group (the "Group") was formed in response to the Commission's decision in the First R&O/Second NPRM. Its purpose is to recommend a set of additional rules for reducing the probability of interference in the 59-64 GHz general unlicensed band. Membership in the group was open to "...entities involved in the research, development, manufacture, sales or distribution of communications products...". Member entities are: Hughes Research Laboratories, Apple Computer, Sun Microsystems, Hewlett-Packard Laboratories, Motorola, Metricom, Rockwell International, and Eaton Division of Cutler Hammer. No qualified entity which sought to join the Group was denied membership.

The Group met monthly during 1996 to develop its recommendations, which are summarized in this report. During the year of activity, the public was kept informed of the Group's progress through postings of meeting minutes on a publicly-accessible Worldwide Web Site:

[http://www-uk.hpl.hp.com/projects/funfair/public/default.html].

The final report and recommendations are also posted at this site for public access. Additionally, in order to promote international harmonization of any sharing rules adopted for the 59-64 GHz band, the Group briefed the Japanese Ministry of Post and Telecommunications on its activities during the early stages of its work.

The Group achieved consensus on its recommendations, which were developed through a process of give-and-take discussion at meetings and via electronic mail. Several key principles guided the Group's decision-making process:

1. The 59-64 GHz Band should not be subdivided
2. No rules should slow the entry of products into the market
3. The simplest set of rules was always to be preferred
4. Rules should seek to reduce, not eliminate, the probability of interference

The Group urges the Commission to adopt the recommendations set forth herein as a comprehensive set of mandatory rules for the 59-64 GHz band. As discussed in the Group's comments in response to the First R&O/Second NPRM, the Commission should not adopt or permit multiple "etiquettes" for the 59-64 GHz band. The rules proposed herein are sufficiently flexible to allow a wide variety of transmitter types and should in no way preclude new technologies; as a result, permitting compliance with alternative "etiquettes" would create a chaotic situation in the band without advancing the Commission's interest in the development of new technologies.

The Group also urges the Commission to continue its current prohibition on use of the 59-64 GHz band while it considers the Group's recommendations. In order to permit product development, manufacture, and marketing to proceed as rapidly as possible, however, the Group urges the Commission promptly to place these recommendations on public notice and to expedite its final adoption of these consensus recommendations.

II. Overview Summary of Recommendations

As discussed in greater detail in Section III, the Group proposes that the Commission adopt the following rules governing operation in the 59-64 GHz band:

A. Peak Emissions Limitation

Presently, average EIRP is limited to 10W and peak EIRP is limited to 1000W. The Group recommends that the Commission limit peak EIRP in the 59-64 GHz band to twice the average EIRP limit, or 20W.

B. Power Limit

Presently, the rules limit emissions, but do not impose a power limit. The Group recommends that the Commission limit the peak power from any transmitter to 500 mW. In addition, the Commission should permit entities to co-locate multiple transmitters at a single location or in a single enclosure without requiring any additional testing of or authorization for the transmitters. To prevent the possibility of producing a high-power coherent beam, the Commission should not allow manufacturers and other entities to incorporate any phase-locking capability into a transmitter.

C. Power Spectral Density

The Group's recommendation limits Peak Power Spectral Density according to the rule: Ppeak<500mW*[BW/100MHz], where BW=transmitter bandwidth.

D. Transmitter Identification Requirement

In order to promote the ability of parties to locate, identify, and resolve interference problems, the Group recommends that the Commission require all transmitters using 0.1 mW or more of power to emit a transmitter identification signal. The transmitter identification would be required to contain three fields: the device's FCC ID number; the device's serial number; and a user-definable field of at least 24 bytes. Manufacturers would be required to submit to the FCC, as part of an application for equipment authorization, information on how interested parties can obtain the data necessary to detect and decode the transmitter identification signal.

E. Coordination Channel

The Group recommends that the Commission set aside 50 MHz of spectrum, from 59.00 to 59.05 GHz, exclusively for the development and creation of a "coordination channel." At first, this band would be used to develop and test alternative approaches for establishing a publicly-accessible channel that would be used to coordinate operation between diverse, non-interoperable transmitters, with a view toward reducing the probability of interference throughout the 59-64 GHz band. Once a consensus standard is developed, the band would be used solely for transmissions consistent with such a standard.

III. Discussion of Rule Recommendations

The following is a detailed rule-by-rule discussion of the Group's recommendations. The full text of all proposed rules is set forth in Appendix A.

A. Peak Emissions Limitation

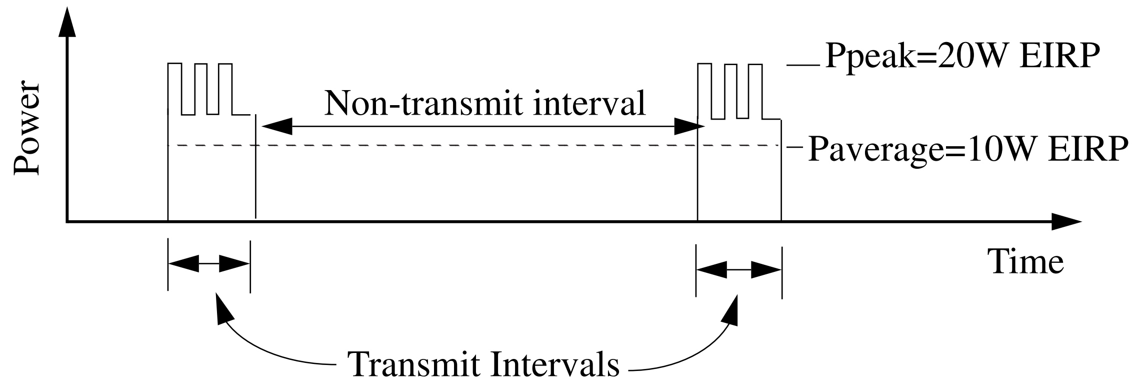
Proposed Rule: Section 15.255(b) would be modified to provide that, within the 59-64 GHz band, the average power density of any emission, measured during the transmit interval, shall not exceed 9 uW/cm^2 at a distance of 3 meters, and the peak power density of any emission shall not exceed 18 uW/cm^2 at a distance of 3 meters. Peak power would be measured with an RF detector that has a detection bandwidth that encompasses the 59-64 GHz band and that has a video bandwidth of at least 10 MHz, or using an equivalent measurement method.

In addition, in order to prevent an internal inconsistency within the rules, the existing Section 15.255(e) (which provides that the provisions of Section 15.35 limiting peak emissions apply to the 59-64 GHz band) would be deleted and the existing Section 15.35 would be amended to make clear that, with respect to the 59-64 GHz band, the rules set forth in Section 15.255 govern peak emissions and the measurement of average power density.

Reason for the Rule: Under Section 15.35(b) of the Commission's existing rules, peak power density levels may equal 100 times the maximum average power density. Within the 59-64 GHz band, the average radiated power density limit is equivalent to 10 watts of Equivalent Isotropic Radiated Power ("EIRP"). In the absence of the above change, peak power pulses of 1000 watts EIRP would be allowed. Such pulses would have the potential to disrupt communications near their point of origin and would have interference ranges of some 2 km more than CW signals of equal average power.

In addition, under Section 15.35(c) of the Commission's existing rules, the average power density level for a device using pulsed operation may be averaged over a complete pulse train or 0.1 seconds, depending on the length of the pulse train. The proposed change would impose a lower limit on average power density levels by specifying that these levels must be measured during the "transmit interval," or the period during which transmission actually is occurring.

A graphical representation of the "transmit interval" power measurement definition is illustrated below:



Impact of the Rule: No negative impact is foreseen.

B. Radiated Power Limitation

Proposed Rule: A new Section 15.255(e) would be added to the rules, which would provide that the total radiated power from any transmitter operating in the 59-64 GHz band shall not exceed 500 mW peak. As above, peak power would be measured with an RF detector that encompasses the 59-64 GHz band and that has a video bandwidth of at least 10 MHz, or using an equivalent measurement method.

In addition, the rule would permit entities to co-locate multiple transmitters in group installations for simultaneous operation, either at a single location or in a single enclosure, as long as each such transmitter has received the necessary FCC equipment authorization. This would make it possible, for example, for users to create a "base station" configuration employing multiple, co-located devices. In these cases, a party would not be required to engage in any additional testing of, or to obtain any additional FCC equipment authorization for, the co-located transmitters. Specifically, parties would not be required to treat co-located transmitters as a "composite system" under Part 15 of the Commission's rules. To prevent the possibility of producing a high-power coherent beam, however, the rule would not permit manufacturers and other entities to incorporate any phase-locking capability into a transmitter. As used in this section, a "transmitter" need not be an integrated radio and computer but could, for example, be a separately-purchasable item (such as a computer card) that receives an equipment authorization. Such a transmitter could operate only with various host devices (such as a computer), or could operate independently.

Finally, the rule would provide that, for purposes of compliance, manufacturers may measure transmitter output power and apply corrections for antenna and circuit losses.

Reason for the Rule: Existing rules allow up to 10 watts of EIRP within the 59-64 GHz band. The recommendation discussed in subsection (A) above would limit peak power to twice this value, or 20 watts. In practice, such high effective powers will be obtained through the use of high gain, highly directional antennas and moderate transmitter powers. However, the theoretical possibility would still exist for transmitters with powers as high as 20 watts to operate with isotropic antennas. Such transmitters could flood an entire region of kilometer dimensions with radiation, thereby greatly reducing the spatial carrying capacity of the region. Since interference area scales in proportion to actual radiated power, one can limit the interference area while still allowing long-range links with high-gain antennas by limiting the radiated power.

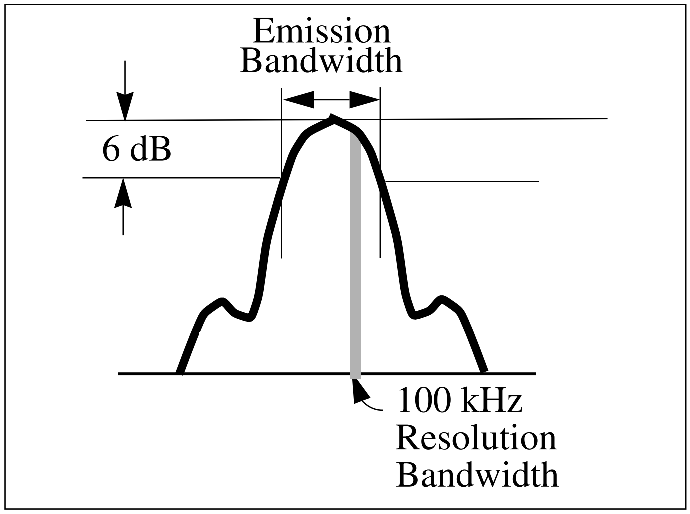
By specifying a measurement bandwidth of 10 MHz, the rule would clearly and unambiguously specify the range of pulse widths that could be detected. A 10 MHz bandwidth is equivalent to a 35 nsec risetime, so pulses of duration 10 nsec or less generally would not be detected, while pulses of duration 100 nsec or greater always would be detected. Spectrum analyzers could be used for this measurement despite the fact they have a maximum detection bandwidth of 3 MHz, by applying corrections to the measured display.

Impact of the Rule: The main impact of the rule would be to limit the use of high power tube transmitters and high power phased arrays of unlicensed transmitters.

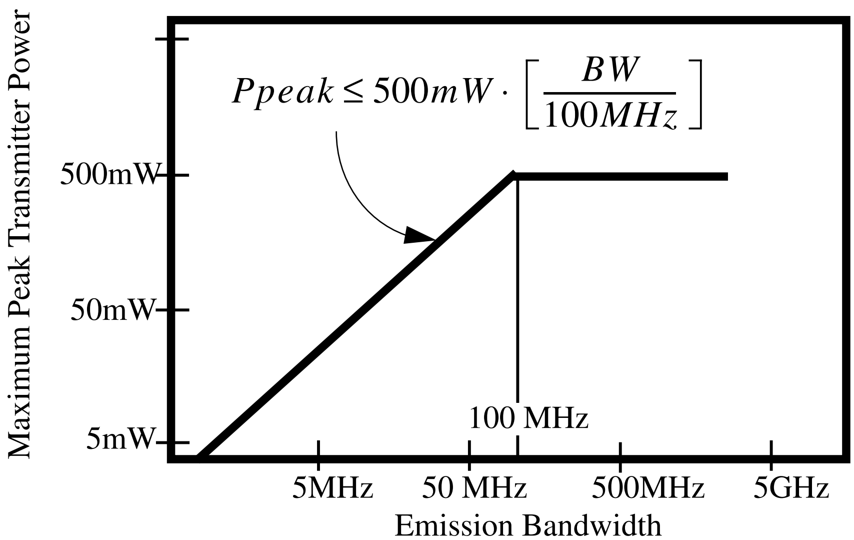
C. Power Spectral Density Rule

Proposed Rule: A new Section 15.255(h) would be added to the rules, which would provide that, in addition to complying with the requirements set forth in Section 15.255(e) (discussed in the previous subsection), transmitters with an emission bandwidth of less than 100 MHz must limit their peak power to the product of 500 mW times their emission bandwidth divided by 100 MHz. For purposes of this subsection, "emission bandwidth" would be defined as the instantaneous frequency range occupied by a steady-state radiated signal with modulation, outside which the radiated power spectral density never exceeds 6 dB below the maximum radiated power spectral density in the band, as measured with a 100 kHz resolution bandwidth spectrum analyzer. The center frequency would be required to be stationary during the measurement interval, even if not stationary during normal operation (e.g. for frequency-hopping devices).

As pictured below, the "emission bandwidth" would be defined such that the power spectral density within the emission bandwidth, as displayed on a spectrum analyzer measuring a transmitter's output, could rise and fall as analyzer's frequency was swept, but that the lowest frequency at which the power spectral density falls 6 dB below the peak value (and never again rises to at least 6 dB below the peak value) would constitute the low end of the emission bandwidth and the highest frequency at which the power spectral density falls 6 dB below the peak value (and never again rises to at least 6 dB below the peak value) would constitute the high end of the emission bandwidth:



With the emission bandwidth thus determined, the peak power rule can be implemented, as shown below:



Reason for the Rule: Narrowband transmitters pose a special interference hazard for broadband communications. If multiple narrowband transmitters occupy a portion of spectrum overlapping that occupied by a broadband receiver, the broadband receiver will be subject to interference from the sum of the powers of the narrowband transmitters. In contrast, a narrowband receiver overlapping a portion of spectrum with a broadband transmitter is subject to interference only from that small portion of the broadband transmitter's power which falls within the narrowband receiver's receiving band. Thus, there is an inherent asymmetry between broadband and narrowband radios in their susceptibility to interference. In addition, because narrow reception bandwidth means less received noise and therefore greater sensitivity, narrowband transmitters have a greater range of interference into narrowband receivers than do broadband transmitters of equal power into broadband receivers.

The potential interference problems created by spectrum sharing among broad- and narrow-band systems can be remedied by requiring all transmitters to have the same peak power spectral density ("PSD"), up to an emission bandwidth of 100 MHz.

Impact of the Rule: Narrowband radio links will have the same carrier-to-noise ratio as broadband links, so communication range and interference range will be independent of link bandwidth.

D. Transmitter Identification Requirement

Proposed Rule: A new Section 15.255(j) would be added to the rules, which would provide that, within any one second interval of signal transmission, each transmitter must transmit a "transmitter identification" at least once. In addition, the rule would require that each application for certification declare that the equipment contains the required transmitter identification feature and specify a method whereby interested parties can obtain sufficient information, at no cost, to enable them to fully detect and decode this transmitter identification information. For purposes of clarity, grantees would be required to make available the information necessary to detect and decode the transmitter identification, but would not be required to make available software or devices for use in detecting or decoding such information.

Upon the completion of decoding, the transmitter identification data block would be required to provide the following fields:

1. The device's FCC Identifier, which would be programmed at the factory and would not be susceptible to modification in the field;
2. The manufacturer's serial number for the device, which also would be programmed at the factory and would not be susceptible to modification in the field; and
3. The provision for at least 24 bytes of data relevant to the specific device, which would be capable of being programmed (and modified) in the field. The recommended content of this field would be information that could be used to assist another user of the 59-64 GHz band in contacting the operator of a particular transmitter.

Transmitters with a peak radiated power of less than 0.1 mW and peak power density of less than 3 nW/cm^2 at a distance of 3 meters from the radiating source would be exempted from the "transmitter identification" requirement.

Reason for the Rule: The transmitter identification requirement would facilitate the diagnosis of problems that arise when two or more systems attempt to utilize the 59-64 GHz band in a conflicting fashion. In particular, it would make it possible for a user experiencing interference to identify an interfering fixed source and to resolve interference from such a source, either by contacting the user of the interfering equipment or by shielding against interference of a known type and location.

Impact of the Rule: No negative impact is foreseen. Modern digital radios are equipped with the necessary programming capability to implement this provision at minimal cost and effort. Inclusion of the information in the 24-byte programmable field is voluntary, so no burden is created. However, it should be noted that the ultimate effectiveness of this provision depends on the degree of voluntary cooperation by equipment users.

E. Coordination Channel

Proposed Rule: A new Section 15.255(i) would be added to the rules, which would restrict use of the 59.0-59.05 GHz band in order to preserve this spectrum for the development and establishment of a publicly-accessible coordination channel. The purpose of the coordination channel would be to coordinate operation between diverse (i.e., non-interoperable) transmitters, with a view toward reducing the probability of interference throughout the 59-64 GHz band.

Currently, neither the Group nor any of its members have developed a specific approach for implementing such a coordination channel. Accordingly, in the short run, entities would be permitted to use this band to develop and test coordination channel approaches, operating jointly or individually under Part 5 experimental authorization(s). Once a consensus approach has been developed and adopted, only transmissions consistent with this approach would be permitted in the band. (Spurious emissions would, of course, be permitted in the band.)

Reason for the Rule: Although there currently does not exist an agreed-upon approach for implementing a "coordination channel" to reduce interference between non-interoperable systems, the Group believes that such a standard could be developed and, once developed, could substantially improve the ability of such systems to share the 59-64 GHz band. Accordingly, the Group recommends setting aside a small portion of the available spectrum (50 MHz, or one percent of the 59-64 GHz band) for the development and possible future implementation of a coordination channel. If the opportunity to reserve spectrum for such a channel is not seized at the outset, it will be impossible later to "clear" spectrum for this use.

If an industry-consensus standard emerges, the Commission would be requested to "amend" its rules (formally, by issuing a blanket waiver, or otherwise) to permit operations consistent with such a standard. Any questions regarding the extent to which compliance with such a standard would be mandatory could be addressed at that time, and need not be resolved now.

Under the proposed rule, manufacturers would be permitted to include in current devices the ability to transmit within the coordination channel, as long as the application for equipment authorization demonstrated with sufficient certainty that this ability could not be activated by an end user. At any time after a coordination channel is established and authorized by the Commission, a manufacturer could “upgrade” existing devices to activate the coordination channel function by, for example, making available to end users software or firmware capable of activating permitted transmissions within the reserved band. Similarly, such equipment could be “upgraded” for experimental license holders. By permitting manufacturers to include in current devices the ability to transmit on the reserved frequencies, the Commission would make it possible to implement a coordination channel at minimal cost and burden.

Impact of the Rule: Other than removing one percent of the band from applications service, the rule would not adversely affect (and, if a coordination channel is implemented, could substantially enhance) use of the 59-64 GHz band.

APPENDIX A
PROPOSED RULES TO IMPLEMENT THE 59-64 GHZ UNLICENSED BAND SHARING PROTOCOL

A. Title 47 of the Code of Federal Regulations, Part 2, is amended as follows:

PART 2 — FREQUENCY ALLOCATIONS AND RADIO TREATY MATTERS; GENERAL RULES AND REGULATIONS

1. The authority citation for Part 2 continues to read as follows:

AUTHORITY: Sections 4, 302, 303, and 307 of the Communications Act of 1934, as amended, 47 U.S.C. Sections 154, 302, 303 and 307, unless otherwise noted.

2. Section 2.1033 is amended by adding paragraph (b)(13), as follows:

Section 2.1033 Application for certification.

* * * * *

(13) Applications for certification of transmitters operating within the band 59.0-64.0 GHz under Part 15 shall be accompanied by an exhibit demonstrating compliance with the provisions of Sections 15.255(g) and (j) of this chapter.

B. Title 47 of the Code of Federal Regulations, Part 15, is amended as follows:

PART 15 — RADIO FREQUENCY DEVICES

1. The authority citation for Part 15 continues to read as follows:

AUTHORITY: Sections 4, 302, 303, 304, 307, and 624A of the Communications Act of 1934, as amended, 47 U.S.C. Sections 154, 302, 303, 304, 307, and 544A.

2. Section 15.35 is amended by revising paragraphs (b) and (c) to read as follows:

Section 15.35 Measurement detector functions and bandwidths.

* * * * *

(b) On any frequency or frequencies above 1000 MHz, the radiated limits shown are based on the use of measurement instrumentation employing an average detector function. When average radiated emission measurements are specified in the regulations, including emission measurements below 1000 MHz, there is also a limit on the radio frequency emissions, as measured using instrumentation with a peak detector function, corresponding to 20 dB above the maximum permitted average limit for the frequency being investigated or, where applicable, to the limits set forth in Section 15.255. Measurement of AC power line conducted emissions are performed using a CISPR quasi-peak detector, even for devices for which average radiated emission measurements are specified.

(c) When the radiated emission limits are expressed in terms of the average value of the emission, and pulsed operation is employed, the measured field strength shall be determined by averaging over one complete pulse train, including blanking intervals, as long as the pulse train does not exceed 0.1 seconds. As an alternative (provided the transmitter operates for longer than 0.1 seconds) or in those cases where the pulse train exceeds 0.1 seconds, the measured field strength shall be determined from the average absolute voltage during a 0.1 second interval during which the field strength is at its maximum value. For devices operating in the 59.0-64.0 GHz band, average field strength shall be determined in accordance with Section 15.255(b) rather than pursuant to this paragraph. The exact method of calculating the average field strength shall be submitted with any application for certification or shall be retained in the measurement data file for equipment subject to notification or verification.

3. Section 15.255 is amended by deleting the introductory NOTE, revising paragraphs (b) and (e), and adding paragraphs (h), (i), and (j), as follows:

Section 15.255 Operation within the band 59.0-64.0 GHz.

* * * * *

(b) Within the 59.0-64.0 GHz band, the average power density of any emission, measured during the transmit interval, shall not exceed 9 uW/cm2 at a distance of 3 meters, and the peak power density of any emission shall not exceed 18 uW/cm2 at a distance of 3 meters. Peak power shall be measured with an RF detector that has a detection bandwidth that encompasses the 59-64 GHz band and that has a video bandwidth of at least 10 MHz, or using an equivalent measurement method.

* * * * *

(e) The total radiated power from any transmitter operating in the 59-64 GHz band shall not exceed 500 mW peak power. Peak power shall be measured with an RF detector that has a detection bandwidth that encompasses the 59-64 GHz band and that has a video bandwidth of at least 10 MHz, or using an equivalent measurement method. Any transmitter that has received the necessary FCC equipment authorization under the rules of this chapter may be mounted in a group installation for simultaneous operation with one or more other transmitter(s) that have received the necessary FCC equipment authorization, without any additional equipment authorization. No transmitter operating under the provisions of this section may be equipped with external phase-locking inputs that permit beam-forming arrays to be realized. For purposes of demonstrating compliance with this paragraph, transmitter output power may be measured and corrections made for antenna and circuit losses.

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(h) In addition to complying with the requirements set forth in Section 15.255(e) of this chapter, transmitters with an emission bandwidth of less than 100 MHz must limit their peak power to the product of 500 mW times their emission bandwidth divided by 100

MHz. For purposes of this paragraph, emission bandwidth is defined as the instantaneous frequency range occupied by a steady-state radiated signal with modulation, outside which the radiated power spectral density never exceeds 6 dB below the maximum radiated power spectral density in the band, as measured with a 100 kHz resolution bandwidth spectrum analyzer. The center frequency must be stationary during the measurement interval, even if not stationary during normal operation (e.g. for frequency-hopping devices).

(i) Only spurious emissions and transmissions related to a publicly-accessible coordination channel, whose purpose is to coordinate operation between diverse transmitters with a view toward reducing the probability of interference throughout the 59.0-64.0 GHz band, are permitted in the band 59.00 - 59.05 GHz.

> NOTE: The band 59.00 - 59.05 GHz has been reserved exclusively for a publicly-accessible coordination channel. The development of standards for this channel shall be performed pursuant to authorizations issued under Part 5 of this chapter.

(j) Within any one second interval of signal transmission, each transmitter must transmit a "transmitter identification" at least once. Each application for equipment authorization must declare that the equipment contains the required transmitter identification feature and must specify a method whereby interested parties can obtain sufficient information, at no cost, to enable them to fully detect and decode this transmitter identification information. Upon the completion of decoding, the transmitter identification data block must provide the following fields:

1. FCC Identifier, which shall be programmed at the factory.

2. Manufacturer's serial number, which shall be programmed at the factory.

3. Provision for at least 24 bytes of data relevant to the specific device, which shall be field programmable. The grantee must implement a method that makes it possible for users to specify and update this data. The recommended content of this field is information to assist in contacting the operator.

Transmitters with a peak radiated power of less than 0.1 mW and peak power density of less than 3 nW/cm2 at a distance of 3 meters from the radiating source are exempted from the requirements of this paragraph (j).

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