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April 20, 1994

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Mr. Ralph A. Haller
Chairman, PCS Task Force
Federal Communications Commission
2025 M Street, NW, Room 5002
Washington DC 20054

RE *ex parte* Presentation in GEN Docket 90-314

Dear Mr. Haller:

At the request of OET staff and in follow up to yesterday's *ex parte discussion*, AT&T/NCR submits the attached technical documentation which proposes certain clarifications to the unlicensed PCS device etiquette rules the Commission has adopted as part of this proceeding in Subpart D of its Rules. (For convenience, a complete copy of the WINForum etiquette rules proposal is also attached) The specific areas addressed by these proposed clarifications and modifications are:

1. Power level definition
2. Spectrum access and transmission burst timing in the asynchronous sub-band
3. Emission bandwidth rules
4. Asynchronous sub-band reaction time

These materials have previously been presented to and are being considered by ANSI C.63, which is developing standards on Methods of Measurement for User PCS devices.

Any questions which may arise should be directed to me.

Sincerely,

FAMathewson

Attachment
cc: Phil Inglis
Richard Engleman, Julius Knapp,Julia Kogan, Renee Licht, David Reed, Greg Rosston

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AT&T Global Information Solutions

TECHNICAL CLARIFICATION AND PROPOSED MODIFICATIONS TO THE ASYNCHRONOUS SUB-BAND RULES OF PART 15 SUBPART D

This paper reviews four items in the Subpart D rules for the asynchronous sub-band. This review offers clarification of the rules, using the WINForum technical rules (etiquette) as its basis. Modifications are proposed that will benefit the use of this new spectrum for Emerging Technologies and the National Information Infrastructure.

Submitted by AT&T
April 19, 1994

TECHNICAL CLARIFICATION AND PROPOSED MODIFICATIONS TO THE ASYNCHRONOUS SUB-BAND RULES OF SUBPART D

Summary

Most of these items have been previously documented by AT&T in filings in the reconsideration process, but some have arisen more recently.

The four points are summarized here and defined in detail in the subsequent sections.

Power Level:

The rules define the power level as the peak power, while the etiquette defined it as mean power and set a peak to average ratio limit. It is proposed that either the etiquette rules be adopted or a measurement technique be defined that permits legitimate efficient modulation techniques for high speed data.

AT&T has previously brought up this issue in the reconsideration process.

Spectrum Access and Transmission Burst Timing in the Asynchronous Sub-band:

This section is incomplete and there are some differences from the etiquette regarding the timing of transmission bursts between cooperating devices. This issue has also been brought up in the reconsideration process, but the solution presented here is preferred over that presented previously.

Emission Bandwidth Rules: These have been referred to as asynchronous sub-band "packing rules". The etiquette permitted a device of any bandwidth to occupy the center part of a 10 MHz segment, while the rules now do not. We believe this extra freedom should be allowed. This has not been brought up previously except in the WINForum etiquette submission.

Also, efficiency can be improved by further relaxing the rules when the 10 MHz segments are contiguous as they now are. This is described and proposed.

Definition of Reaction Time for the Asynchronous Sub-band: Both the etiquette and the subpart D rules are deficient in this respect. The reaction time specification appears to conflict with the monitoring time requirement. We propose a definition of reaction time which will clarify the requirements.

TECHNICAL CLARIFICATION AND PROPOSED MODIFICATIONS TO THE ASYNCHRONOUS SUB-BAND RULES OF SUBPART D

1. The Power Level Specification

The Subpart D rules establish the power level requirements based on a peak power specification while the WINForum etiquette rules recommended a mean power specification with a limit on the peak envelope power to mean power ratio of 10 dB. AT&T feels that either the WINForum recommendation should be adopted or the peak power should be measured with some minimal averaging method. A video filter applied to the envelope has been suggested to effect this averaging. Peak power is not strictly defined elsewhere, so the rules could remain as they are now worded and the problem can be solved in the measurement procedures if this is preferred.

The peak envelope power is defined by the ITU as the average power of the maximum cycle of an emission. This, in effect, is a request that the "peak" power of the Subpart D specification should not refer to peak envelope power.

The effect of defining the transmitted power as the peak envelope power would be to encourage constant envelope modulation techniques and render more advanced techniques impractical. Yet advanced techniques with varying envelope power can provide up to 2 times the data throughput density of conventional constant envelopes techniques. Table 1 compares the computed throughput density and crest factor for some common and advanced modulation techniques. The throughput density is proportional to the actual efficiency achievable in terms of information flow per MHz per cell in a self interference limited small cell environment. The advanced techniques with high peak-to-average ratio are 50% to 60% more efficient than the techniques providing constant envelopes.

In addition, the peak-to-average ratios for the BPSK and QPSK techniques are higher as a result of the limited RF emission bandwidth. This narrow bandwidth is sufficient to allow optimum signaling speed with minimum spectrum occupancy. In this case also, limiting the peak envelope power would tend to encourage less than optimum signaling speeds in a given amount of spectrum.

The potential for high throughput density and spectrum efficiency should be encouraged, while a specification based on controlling the peak envelope power virtually rules out this potential.

Historically, peak power has been limited to control interference. However, in the case of high signaling rate digital data signals, the interference potential is almost totally independent of the envelope variation at the source because:

- Multipath reflections convert a wide bandwidth signal with constant envelope to a varying envelope signal at any receiver not equalized to the signal.
- Operation in dense throughput locations where optimum coexistence efficiency is important is self interference limited and composite interference levels are due to a large number of signal sources. Such interference has a high crest factor.
- A wideband signal intercepted by a narrowband receiver has high peak envelope variations at the receiver output decision point.
- Interference in adjacent or nearby channels due to spurious emissions normally has a high crest factor regardless of the form of the source

The only case where the source crest factor is of significance concerning interference potential is when the interfering signal is an isolated source and the receiver with which it interferes has equal or greater bandwidth than the source emission.

TECHNICAL CLARIFICATION AND PROPOSED MODIFICATIONS TO THE ASYNCHRONOUS SUB-BAND RULES OF SUBPART D

Interference envelopes from high signaling rate digital data signals will have envelope variations approaching that of random noise regardless of the envelope variations of the source. Thus, potential interference is not a legitimate reason to discourage variations in the envelope power at the source at the expense of achieving optimally efficient use of the spectrum.

AT&T is working within the ANSI C63 committee to develop a power measurement specification which will permit the appropriate averaging to allow legitimate modulation envelope variations. An attachment to this paper is a set of presentation charts which were presented and discussed at the March, 1994 meeting of the ANSI C63 SC7 committee. These charts present more detail on the topic discussed above.

TABLE 1. MODULATION STRUCTURES COMPARISON

Modulation	Peak/ Average Power (dB)	Signaling Rate /B (99%)	Medium Reuse Factor (η in %)[1]	Throughput Density Mb/s/MHz/ cell
BPSK[2]	3.4	0.67	6.6	0.044
MSK	0	0.87	6.6	0.057
QPSK[2]	3.0	1.33	5.5	0.073
16 OFDM/QPSK[2]	15	1.33	5.5	0.073
8PSK[2]	3.0	2.00	3.8	0.076
16 QAM[2]	4.8	2.67	3.4	0.091
4 Tone/16 QAM[2]	10.8[3]	2.67	3.4	0.091

Notes:

1.0 The medium reuse factor gives an estimate of the throughput density in a 2 dimensional, small cell deployment area. It is the percentage of cells that can have simultaneous transmissions without destructive interference in a homogeneous propagation environment limited by cochannel interference. The propagation index is assumed to be 3.5 (-10.5 dB for each doubling of range). It is given by the following:

$$\eta = [2 + SIR^{1/n}]^{-2}.$$

SIR is the Signal to Interference power ratio necessary to meet the error rate (10^{-8}) and n is the propagation index (3.5).

This relationship is derived in the paper distributed to the WINForum technical committee in September, 1992, "Tradeoff Between Modulation Bandwidth Efficiency and Medium Reuse Efficiency", IEEE P802.11/91-22, by Kiwi Smit of NCR. It is based on the article "Universal Digital Communications" by Donald C. Cox, Proceedings of the IEEE, Vol. 75, No. 4, April 1987.

2.0 The peak/average factor in all cases except MSK is that which results with raised cosine filtering with a total (rf) bandwidth of 1.5/T, where T is the symbol time.

3.0 Multi-tone adds $10 \log_{10} n$ dB to the peak/average crest factor, where n is the number of tones. This type of operation can provide high signaling speed in Local Area Network data applications by the use of long symbol times to counter delay spread.

TECHNICAL CLARIFICATION AND PROPOSED MODIFICATIONS TO THE ASYNCHRONOUS SUB-BAND RULES OF SUBPART D

2. Asynchronous Spectrum Access and Transmission Burst Timing

The Etiquette wording

4.2 Asynchronous Transmission Bursts

4.2.1 An asynchronous transmission burst is a series of transmissions from one or more transmitters acting cooperatively. Any intra-burst gap shall not be greater than 25 microseconds. No burst duration shall be greater than 10 milliseconds.

4.2.2 *Individual bursts* shall be separated by at least a random-duration interval uniformly distributed between *50 microseconds and 375 microseconds.*

5.2 Spectrum Access in the Asynchronous Sub-band

5.2.1 Before each burst is transmitted, transmitters shall monitor the intended occupied bandwidth. The monitoring period shall be at least 50 microseconds.

5.2.2 Once a burst has started, participating transmitters are not required to monitor the channel, providing the gap between transmissions does not exceed the intra-burst gap 4.2.1.

5.3 Spectrum Access Criteria and Selection

5.3.1 If monitoring required in paragraphs (--) 5.2 indicate that the particular occupied bandwidth selected is in use, transmission may not proceed: there are two possible spectrum access alternatives.

5.3.1.2 After the occupied bandwidth becomes idle, the transmitter shall wait a deference time chosen from a uniform random distribution between X and *15X*, where X = 10 ms for Isochronous devices; *x = 50 microseconds for asynchronous systems.* At the end of this period, the transmitter may again proceed according to the appropriate rule 5.1 or 5.2.

The R&O wording

15.323 (c) (1)

Before initiating a transmission burst, devices must monitor the spectrum window they intend to use for a period of time that is at least 50 microseconds.

15.323 (c) (4)

After completion of a transmission burst, an *individual device or cooperating group of devices* must cease transmission and wait a deference time randomly chosen from a uniform random distribution ranging from *50 to 750 microseconds* after which time an attempt to access the band again may be initiated. For each ------.

15.323 (f)

An asynchronous transmission burst is a series of transmissions from one or more transmitters acting cooperatively. The transmission burst duration from one device or group of devices acting cooperatively shall be no greater than 10 milliseconds. *Any intra burst gap between cooperating devices shall not exceed 25 microseconds.*

15.323 (g)

Individual unit intra burst transmissions shall be separated by a uniform random-duration interval evenly distributed between *50 and 375 microseconds.*

TECHNICAL CLARIFICATION AND PROPOSED MODIFICATIONS TO THE ASYNCHRONOUS SUB-BAND RULES OF SUBPART D

Comments

Both the WINForum Etiquette and the R&O have inconsistencies. Refer to the R&O, section 15.323 (f) and (g). The R&O appears to make a distinction between "one or more" transmitters acting cooperatively [15.323 (f)] and an "individual unit" [15.323 (g)] with respect to the transmission burst definition. Also, section 15.323 (c) (4) disagrees with [15.323 (g)] with respect to the value of the deference time.

The word "intra burst" in 15.323 (g) is probably intended to be "inter burst" and "individual units" should be treated the same as "one device or cooperating group of devices". The whole paragraph should be dropped.

The problem also occurs in the etiquette. Section 4.2.2 of the etiquette is inconsistent with section 5.3.1.2. This is probably the source of the confusion in the R&O. Originally, section 4.2.2 of the etiquette was to apply to a transmitter continuously engaged in sending bursts. The deference time was shorter for a device or group of devices already engaged in exchanging bursts than for a device or group initially accessing the spectrum.

This inconsistency should be resolved in the etiquette by dropping section 4.2.2. The complimentary change in the R&O is to drop section 15.323 (g).

What is "one transmitter acting cooperatively"? Both the etiquette and the R&O use the term.

Another inconsistency shows up in a parsing of the R&O. The situation where a station initially tries to access spectrum and fails is not covered. Section 15.323 (c) (4) only covers the case after a device completes a transmission burst. This section should be reworded:

> "15.323 (c) (4) After completion of a transmission burst or when the spectrum is busy upon the initial access attempt, an individual device or cooperating group of devices must wait a deference time randomly chosen from a uniform random distribution ranging from 50 to 750 microseconds after the spectrum becomes idle. After this time an attempt to access the band again may be initiated. For each -------."

It is important that the deference time start after the channel becomes idle, not at the time of the access attempt.

TECHNICAL CLARIFICATION AND PROPOSED MODIFICATIONS TO THE ASYNCHRONOUS SUB-BAND RULES OF SUBPART D

3. Asynchronous Sub-Band Emission Bandwidth Rules (Packing Rules)

The Etiquette wording

3.1 Asynchronous Bandwidth Limits

The occupied bandwidth shall be between 500 KHz and 10 MHz.

All devices of less than 2.5 MHz occupied bandwidth in the asynchronous sub-band will occupy the spectrum nearest the sub-band edges or exactly at the band centers, before otherwise occupying further spectrum in the center half of the sub-band, while devices of more than 2.5 MHz occupied bandwidth will occupy spectrum in the center half of the sub-band before occupying the spectrum near the sub-band edges. Devices of occupied bandwidth of less than 1.0 MHz may not occupy the center half of the sub-band unless they are nominally centered in the middle of their sub-band.

The R&O wording

15.323 Specific requirements for asynchronous operation in the 1900-1920 MHz sub-band.

(a) Operation shall be contained within one of two 10 MHz channels: 1900-1910 MHz or 1910-1920 MHz. The emission bandwidth of any intentional radiator operating in this sub-band shall be no less than 500 kHz.

(b) All systems of less than 2.5 MHz emission bandwidth shall first occupy spectrum beginning nearest a channel edge, while systems of more than 2.5 MHz emission bandwidth will first occupy the center half of a channel. Devices with an emission bandwidth of less than 1.0 MHz may not occupy the center half of a channel if other spectrum is available.

Comments

The R&O converted to two channels to account for the additional spectrum acquired. This was necessary because the rules were written to apply to 10 MHz segments while the etiquette applies to a single 10 MHz sub-band.

However, the R&O leaves out the wording that would permit narrow bandwidth systems to occupy spectrum at the channel centers. The etiquette wording should be reinstated with regard to this.

The problem which these rules alleviate occurs if narrowband devices operate on multiple different frequencies near the center of the 10 MHz channel. Such devices can block out a device which attempts to occupy a bandwidth which overlaps the bands of the multiple devices because the rules cannot assure that all of the narrowband channels will be off at the same time.

Any device should be permitted to occupy the center of the band, regardless of it's emission bandwidth. This would assure that only one channel would contend with the wideband device.

TECHNICAL CLARIFICATION AND PROPOSED MODIFICATIONS TO THE ASYNCHRONOUS SUB-BAND RULES OF SUBPART D

Another Packing Arrangement

There is a potentially better packing arrangement with 20 MHz of contiguous spectrum.

As an example, allow systems of more than 2.5 MHz emission bandwidth to operate anywhere within the sub-band, but keep 5 MHz clear of multiple narrowband users (under 2.5 MHz) in the center of each 10 MHz segment (this latter is done now). The following table shows this:

Frequency Range	Bandwidth of Range	Permitted Emission Bandwidths
1900-1902.5	2.5 MHz	500 KHz to 2.5 MHz.
1902.5 - 1907.5	5.0 MHz	Above 2.5 MHz unless: 1. 1905 MHz is the nominal center of the emission band or 2. the emission bandwidth is above 1.0 MHz and there is no other segment available and below 10 MHz
1907.5 - 1912.5	5.0 MHz	500 KHz to 10 MHz.
1912.5 - 1917.5	5.0 MHz	Above 2.5 MHz unless: 1. 1915 MHz is the nominal center of the emission band or 2. the emission bandwidth is above 1.0 MHz and no other segment is available and below 10 MHz.
1917.5 - 1920	2.5 MHz	500 KHz to 2.5 MHz.

TECHNICAL CLARIFICATION AND PROPOSED MODIFICATIONS TO THE ASYNCHRONOUS SUB-BAND RULES OF SUBPART D

4. Definition of Reaction time

The Problem

Section 15.323 (c) (1) requires that a device operating in the asynchronous sub-band must monitor the channel for at least 50 microseconds before initiating a burst, while 15.323 (c) (5) requires that the maximum reaction time be 35 or 50 microseconds. The words "reaction time" are not defined and the rules specifying it in the asynchronous sub-band appear to be contradictory.

The etiquette document has the same apparent contradictions.

The reaction time in the asynchronous sub-band rules was originally meant to be:

1. The time to detect the presence of carrier and decide to defer and
2. The maximum time for a device to determine that carrier is absent and turn on its own carrier.

It was felt that no specification was required on the carrier off detection time.

Function number 2 appears to conflict with the minimum monitoring time of 50 microseconds.

Further, reaction time is also specified for the isochronous sub-band and the actual requirements may be different in the two sub-bands. Section 15.321 (c) (7) specifies the reaction time for devices operating in the isochronous sub-band with the same wording as section 15.323 (c) (5) for the asynchronous sub-band.

The wording of the rules are repeated in a later section of this document.

The Intent of the Rules in the Asynchronous Sub-band

The following is the writer's understanding of the original intent of the rules as perceived during the WINForum technical committee deliberations. They are from notes and from memory.

The problem to be controlled by the reaction time requirement is the successful access case; that is, it is the case where carrier is not present during the monitoring period. The device attempting to access the spectrum may, after determining that carrier is not present, quit monitoring, issue a command to turn on its own carrier and go into a temporary state where it isn't monitoring while waiting for its carrier to come on. The time between when monitoring ends and the actual turn-on of carrier will be referred to as "dead time". Another device carrier is likely to appear during the dead time and not be sensed. Thus, if the dead time lasts too long, a high probability of collision will occur. It was intended that the maximum "on" detection time plus the dead time be less than or equal to the 35/50 microsecond specification. A trade-off is permitted; if the device can sense carrier quickly, it is permitted to have a slow carrier turn on time and vice versa.

Note that the maximum "on" detection time is the time required to sense that carrier is not on. Sensing that carrier is not on is not the same as sensing that carrier has gone off after being on. The time to sense carrier off after it has been on is intentionally not controlled.

The requirements were intended to be:

1. Devices should detect the presence of carrier within 35/50 microseconds minus their maximum dead time. That is, the reaction time is the maximum "on" detection time plus the dead time.

2. Even if the device does not sense carrier during it's maximum "on" detection time, it should continue to monitor for at least 50 microseconds in case the other carrier is not on at the beginning of the monitor period, but comes on during the monitor period.

The fact that the carrier may contain a 25 microsecond intraburst gap during the monitoring period was not considered in calculating a reasonable value for the reaction time. However, considering the minimum emission bandwidth of 500 kHz of the asynchronous sub-band, it should be possible to meet the requirement in this sub-band with the 25 microsecond gap present.

Recommendation

Add a definition of reaction time in section 15.303.

( ) Reaction time - For isochronous devices, the time required for a device to detect carrier in a spectrum/time-window being monitored. For asynchronous devices, the time required for a device to sense the presence or absence of carrier plus the time to complete the appropriate reaction resulting from the carrier condition sense. This includes the carrier turn on time after sensing the channel carrier absence condition.

The Rules Covering the Case

The part of the rules affecting the reaction time question are repeated here for convenience. Some further recommended modifications are also denoted The italicized words don't appear in the rules now but are recommended for addition.

15.323(c)(1)
Before initiating a transmission burst, a device *or one of a group of cooperating devices* must monitor the spectrum window they intend to use for a period of time that is at least 50 microseconds.

15.323(c)(4)
After completion of a transmission burst *or when the spectrum is busy upon the initial access attempt*, an individual device or cooperating group of devices must wait a deference time randomly chosen from a uniform random distribution ranging from 50 to 750 microseconds *after the spectrum becomes idle. After this time* an attempt to access the band again may be initiated.

15.323 (c) (5)
The monitoring system bandwidth must be equal to or greater than the emission bandwidth of the intended transmission and shall have a maximum reaction time less than 50xSQRT(1.25/emission bandwidth in MHz) microseconds for signals at the applicable threshold level but shall not be required to be less than 50 microseconds. If a signal is detected that is 6 dB or more above the threshold level, the maximum reaction time shall be 35xSQRT(1.25/emission bandwidth in MHz) microseconds but shall not be required to be less than 35 microseconds.

TECHNICAL CLARIFICATION AND PROPOSED MODIFICATIONS TO THE ASYNCHRONOUS SUB-BAND RULES OF SUBPART D

The Relevant WINForum Etiquette Wording

5.2.1 Before each burst is transmitted, transmitters shall monitor the intended occupied bandwidth. The monitoring period shall be at least 50 microseconds.

5.3.1.2 After the occupied bandwidth becomes idle, the transmitter shall wait a deference time chosen from a uniform random distribution between X and 15X, where X = 10 ms for Isochronous devices; x = 50 microseconds for asynchronous systems. At the end of this period, the transmitter may again proceed according to the appropriate rule 5.1 or 5.2.

5.4.3 Maximum Reaction Time

The maximum reaction time of the monitoring system will be less than 50 x SQRT (1.25/B) microseconds for signals at the applicable threshold level (5.4.2) but shall not be required to be less than 50 microseconds. For a signal that is 6 dB or more above the applicable threshold level, the maximum reaction time shall be 35 x SQRT (1.25/B) microseconds but shall not be required to be less than 35 microseconds.

"B" is defined as Occupied Bandwidth in MHz.

WINFORUM ETIQUETTE RULES PROPOSAL

1.0

1.1 Transmitters in this band shall be used only for digitally modulated transmission, and shall be limited by power, frequency use, transmission time, and Spectrum access mechanism so as to provide fair access and coexistence for short range systems.

1.2 Definitions.

1.2.1 Isochronous Transmitters shall be defined as transmitters that emit at regular intervals, as typified by time-division voice systems.

1.2.2 Asynchronous Transmitters shall be defined as transmitters that emit at irregular intervals, as typified by Local Area Network (LAN) data systems.

1.2.3 Transmit Power.

The transmit power "P" is the maximum of the mean radiated power over any interval of continuous transmission.

1.2.4 Measurements.

All power measurements will be made over an interval of continuous transmission.

1.2.5 Marker Transmission.

A marker transmission is a low-capacity, predominately one-way transmission used by a device to identify itself to other inter-operable devices within its communication range. The content and purpose of marker transmissions shall be limited to minimal control and signaling information as needed by a device to establish or maintain communications with other inter-operable device.

1.2.6 Occupied Bandwidth

Occupied bandwidth is that bandwidth that contains 99% of the total transmit power, including allowance for frequency instability and spurious emissions.

1.2.7 Sub-Bands

The available band shall be divided into two equal sub-bands; one sub-band for Isochronous operation (the Isochronous sub-band) located in the lower half of the unlicensed PCS band and one sub-band for asynchronous operation (the asynchronous sub-band) located in the upper half of the unlicensed band.

2.0 Transmit Power Limits

2.1 Maximum Transmit Power

2.1.1 The transmit power "P" shall not exceed

100 * sqrt(B) milliwatts

where "B" = occupied bandwidth in MHz.

2.1.2 Further, the transmit power shall not exceed 3 milliwatts in any 3-KHz wide band.

2.1.3 Power -- Bandwidth Example Table

Power in mW	Bandwidth in MHz
32	0.1
52	0.3
100	1.0
173	3.0
316	10.0

2.1.4 The peak envelope power shall not exceed the transmit power by more than 10 dB.

2.2 Reduction with Antenna Gain

The permitted transmit power shall be reduced by the amount in dB that the maximum directional gain of the antenna exceeds 3 dBi.

2.3 Emission Limits

This section applies to all emissions not within the occupied bandwidth regardless of cause and includes spurious emissions. The measurement bandwidth will be the equal to the occupied bandwidth. The emission limits are specified relative to a reference power which is the lesser of the maximum transmit power for the occupied bandwidth as given in section 2.1 or 113 milliwatts.

2.3.1 Inter-1.25 MHz Frequency Segment Emissions

The total power, emitted by an intentional radiator operating in a 1.25 MHz frequency segment , detected in the immediately adjacent 1.25 MHz segment, shall be at least 30 dB below the power permitted that radiator.

The total power emitted by an intentional radiator in the band between 1.25 MHz and 2.5 MHz measured from the edge of the occupied segment, shall be at least 50 dB below the transmit power permitted for that radiator.

The total power emitted by an intentional radiator in any frequency segment more than 2.5 MHz from the edge of the occupied bandwidth, shall be at least 60 dB below the transmit power permitted for that radiator.

2.3.2 Out of Sub-band Emissions.

The total power emitted by an intentional radiator , in the third and subsequent 1.25 MHz frequency segments beyond the sub-band edge, shall be at least 60 dB below the transmit power permitted an intentional radiator operating with an 1.25 MHz occupied bandwidth.

2.3.2.1 Within the PCS band (licensed and unlicensed).

The total power emitted by an intentional radiator in the first 1.25 MHz frequency segment beyond the sub-band edge, shall be at least 30 dB below the transmit power permitted an intentional radiator operating with an 1.25 MHz occupied bandwidth.

The total power emitted by an intentional radiator, in the second 1.25 MHz frequency segment beyond the sub-band edge, shall be at least 50 dB below the transmit power permitted an intentional radiator operating with an 1.25 MHz occupied bandwidth.

2.3.2.2 Outside of the PCS band (licensed and unlicensed).

The less stringent of the limits of 2.3.2.1 or CFR 47.15.209 applies.

2.3.3 Out-of-Occupied Bandwidth Emissions for Isochronous Transmissions

The total power emitted by an intentional radiator in the band between 1 B and 2 B measured from the center of the occupied bandwidth, shall be at least 30 dB below the transmit power permitted for that radiator.

The total power emitted by an intentional radiator in the band between 2 B and 3 B measured from the center of the occupied bandwidth, shall be at least 50 dB below the transmit power permitted for that radiator.

The total power emitted by an intentional radiator in the measurement bandwidth more than 3 B from the center of the occupied bandwidth, shall be at least 60 dB below the transmit power permitted for that radiator.

3.0 Frequency Limits

3.1 Asynchronous Bandwidth Limits

The occupied bandwidth shall be between 500 KHz and 10 MHz.

All devices of less than 2.5 MHz occupied bandwidth in the asynchronous sub-band will occupy the spectrum nearest the sub-band edges or exactly at the band centers, before otherwise occupying further spectrum in the center half of the sub-band, while devices of more than 2.5 MHz occupied bandwidth will occupy spectrum in the center half of the sub-band before occupying the spectrum nearer the sub-band edges. Devices of occupied bandwidth of less than 1.0 MHz may not occupy the center half of the sub-band unless they are nominally centered in the middle of their sub-band.

3.2 Isochronous Occupied Bandwidth Limits

The Isochronous sub-band shall be divided into segments 1.25 MHz in width. Isochronous frequency Segments are 1.25 MHz apart, beginning at the lower edge of the frequency band of the unlicensed PCS Band. No occupied bandwidth greater than 1.25 MHz is permitted in this sub-band; narrower bandwidths are permitted within each 1.25 MHz segment.

3.3 Isochronous Occupied Bandwidth Limits

In the Isochronous sub-band, the occupied bandwidth shall be between 50 KHz and 1.25 MHz.

3.4 Spectrum Sharing

Cross-over between sub-bands will be governed by adherence to the rules of the sub-band entered.

3.5 Frequency Stability

In the Asynchronous Sub-band: the frequency stability of the intentional radiator shall be equal to or better than +/- 10 ppm over 10 milliseconds or the interval between Listen Before Transmit monitorings, whichever is shorter

In the Isochronous Sub-band: the frequency stability of the intentional radiator shall be equal to or better than +/- 10 ppm over 1 hour or the interval between Listen Before Transmit monitorings, whichever is shorter

4.0 Time Limits

4.1 Isochronous Frame Period

The frame period of an Isochronous transmitter shall be 10 milliseconds/N where N is a positive integer.

Devices operating in the Isochronous sub-band that implement time division for the purposes of maintaining a duplex connection on an occupied bandwidth shall maintain their frame repetition rate with frequency stability of at least 50 ppm. Devices which further divide access in time in order to support multiple communication links on an occupied bandwidth shall maintain their frame repetition rate with frequency stability of at least 10 ppm. The jitter introduced at the two ends of such a communication link shall not exceed 25 microseconds for any two consecutive transmissions.

4.2 Asynchronous Transmission Bursts

4.2.1 An asynchronous transmission burst is a series of transmissions from one or more transmitters acting cooperatively. Any intra-burst gap shall not be greater than 25 microseconds. No burst duration shall be greater than 10 milliseconds.

4.2.2 Individual bursts shall be separated by at least a random-duration interval uniformly distributed between 50 microseconds and 375 microseconds.

4.3 Unacknowledged marker transmissions from a device shall be limited to 30 seconds. After that period the spectrum access procedure shall be required to initiate further marker transmissions.

5.0 Spectrum Access

5.1 Spectrum Access in the Isochronous Sub-band

5.1.1 Before initiating transmission, devices shall have monitored the intended occupied bandwidth within the portion(s) of the Isochronous frame(s) in which they intend to transmit over the period of at least 10 milliseconds to determine if the access criteria are met.

5.1.2 If the power detected during the monitoring (as described in paragraph 5.1.1 or 5.1.3) can be decoded as a connection signal from an interoperable device (the initiating device denoted "A"), transmission to establish a duplex connection to that device (A) on that time/frequency combination may begin without further monitoring. Except when device A initiates a connection signal under paragraph 5.1.3, device A (initiating the connection) shall monitor both its intended transmit and intended receive times. Spectrum/time slot access selection for the initiating device (A) shall be based on the higher measured power of the intended transmit or receive intervals.

5.1.3 Before initiating transmission, devices which are in a state which prevents them from monitoring during their intended transmit interval shall monitor the portion(s) of the Isochronous frame(s) in which they intend to receive over a period of a least 10 milliseconds to determine if the access criteria are met so long as the monitored spectrum is within the 1.25 MHz frequency segment(s) already occupied by that device or co-located (within one meter) co-operating group of devices. The receive monitoring interval must total a least 50% of the 10 millisecond interval.

5.1.4 Neither section 5.1.2 nor 5.1.3 shall be used create a "bypass" procedure whereby devices may extend the range of spectrum occupied over space or time for the purpose of denying fair access to spectrum to other devices.

5.1.5 Succeeding transmissions may be sent without further monitoring, as long as the occupied bandwidth is entirely within the Isochronous sub-band.

5.1.6 With the exception of marker transmissions, all access attempts initiated after following the procedure in section 5.1.1 must stop after one second if no acknowledgment has been received by the initiating device. Further access attempts must repeat the procedure outlined in section 5.1.1.

5.2 Spectrum Access in the Asynchronous Sub-band

5.2.1 Before each burst is transmitted, devices shall monitor the intended occupied bandwidth. The monitoring period shall be at least 50 microseconds.

5.2.2 Once a burst has started, participating transmitters are not required to monitor the occupied bandwidth, providing the gap between transmissions does not exceed the intra-burst gap 4.2.3.

5.3 Spectrum Access Criteria and Selection

5.3.1 If monitoring required in paragraphs 5.1 or 5.2 indicates that the particular occupied bandwidth selected is in use, transmission may not proceed; there are two possible spectrum access alternatives.

5.3.1.1 Another intended occupied bandwidth may be selected and monitored.

5.3.1.2 After the occupied bandwidth becomes idle, the transmitter shall wait a deference time chosen from a uniform random distribution between X and 15X, where X = 10 ms for Isochronous devices; x = 50 microseconds for asynchronous devices. At the end of this period, the transmitter may again proceed according to the appropriate rule 5.1 or 5.2.

5.3.2 For asynchronous devices, The range from which the deference time is chosen shall double on each occasion that an access attempt fails (after the interburst interval), until an upper limit of 240X is reached. The range shall be reinitialized after each successful access attempt.

5.3.3 Each device shall implement a spectrum access mechanism adequate to prevent catastrophic congestion.

5.4 Monitoring Requirements

5.4.1 The monitoring mechanism shall operate via the transmitting antenna, or one that includes the coverage area of the transmitting antenna.

5.4.2 Monitoring Threshold

5.4.2.1 Isochronous Monitoring Threshold

A device detecting energy below 30 dB above the thermal noise power in the intended occupied bandwidth for a selected time/frequency combination may access it without further searching.

If no "free" time/frequency combination is available, and at least 40 duplex system access time/frequency combinations are defined for the system, the time/frequency combination with the lowest power below a monitoring threshold of 50 dB above the thermal noise power in the intended occupied bandwidth may be used. A device utilizing this mechanism must have monitored all access intended time/frequency combinations within the last 10 seconds and must verify within the 20 milliseconds immediately preceding spectrum access that the detected power of the time/frequency combination selected is no higher than the previously detected value. The resolution for power measurements need not be more accurate than 6 dB.

No device or group of cooperating devices within 1 meter of each other shall occupy more than three 1.25 MHz Isochronous frequency segments during any frame.

5.4.2.2 Asynchronous Monitoring Threshold.

The threshold shall be within 32 dB of the thermal noise power in the intended occupied bandwidth.

5.4.3 Maximum Reaction Time

The maximum reaction time of the monitoring system will be less than 50 x SQRT (1.25/B) microseconds for signals at the applicable threshold level (5.4.2) but shall not be required to be less than 50 microseconds. For a signal that is 6 dB or more above the applicable threshold level. The maximum reaction time shall be 35 x SQRT (1.25/B) microseconds but shall not be required to be less than 35 microseconds.

"B" is defined as Occupied Bandwidth in MHz.

5.4.4 The threshold decision shall be made based on the maximum power detected during the monitoring interval.

5.4.5 Every transmitter shall discontinue transmission in case of either absence of information to transmit or failure.

5.5 Dynamic Power Control and Monitoring Sensitivity

Transmitters that radiate power that is lower than the maximum specified in section 2 may increase their detection threshold by one dB for each one dB that the transmitter power is below the maximum permitted.