**IEEE 802.11**
**Wireless Access Method and Physical Layer Specification**

**Title:** **Recommendation Modification of Proposed Wording of the Physical Layer Draft Specification for 2.4 GHz Draft Frequency Hop Spread Spectrum Media, Doc 94/68, March 1994**

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**Abstract:** In previous submissions presented to the 802.11 committee by this and other authors, proposals and justifications for Frequency Hop performance specifications have been presented. It is the scope of this submission to summarize those positions and present modified wording and in some cases additional specifications for inclusion in the PHY spec. Topics include transmitter and receiver RF performance and timing specifications.

## Introduction

Each section of this submission is referenced to a corresponding section in the draft specification, 94/68. Where appropriate each section contains three parts, a discussion of basic issues. a proposed change to the wording of the specification with strikeouts for text removal and underline for text addition, and finally a draft motion to adopt the proposed change in wording.

## 4.7.4 Occupied Channel Bandwidth.

**Discussion:**
Bandwidth Interpretation

In the May 1993 meeting, the FCC requirement for a 20 dB bandwidth of less than 1 MHz was discussed. It was recognized at that meeting, that the FCC specification might refer to the bandwidth of 99% of the transmitted power or the more demanding requirement that the spectrum to be down at least 20 dB at ± 500 KHz from the transmitted center frequency. Rather than presume the FCC intent, it was decided to provide a modulation format, GFSK, with a minimum deviation of ±160 kHz. If the FCC would ultimately rule that the 20 dB bandwidth prevailed, then the maximum deviation would be ±175 kHz. If the FCC would ultimately rule that the 99% occupancy interpretation of bandwidth would prevail, then the deviation maximum would be ±210 kHz.

Frequency Tolerance

The FCC rules do not state or imply specific center frequencies for frequency hop transmitters in the 2.4 to 2.4835 MHz band. The occupied bandwidth of a transmitter need not be reference to any given center frequency for FCC reasons. For interoperability reasons, the center frequency must be defined for the 802.11 specification with tolerance. In terms of complying with the FCC bandwidth restriction, only the bandwidth of the transmitted signal need be considered. There is no need to reference the IEEE 802.11 frequencies or the tolerance this standard allows with respect to these nominal frequencies. These are separate issues.

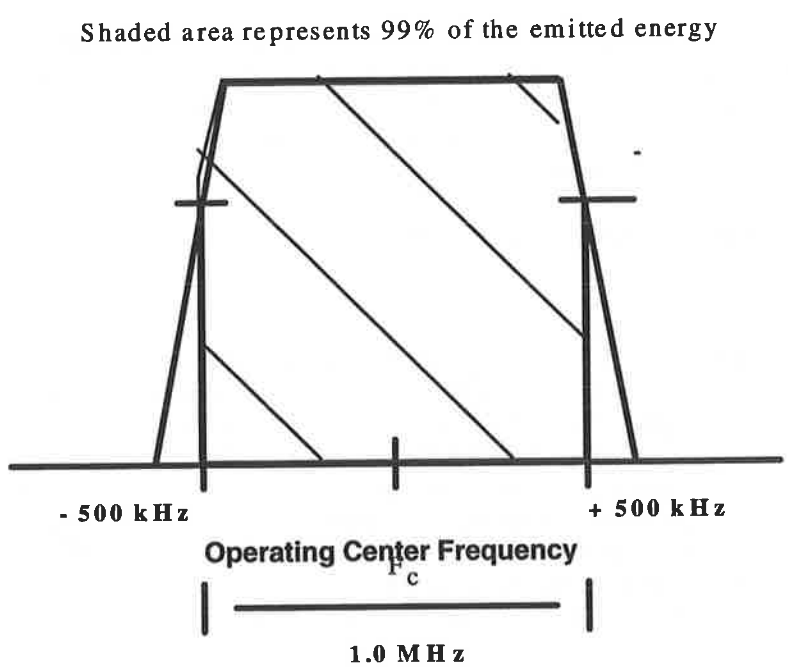
With than background, the following change to 4.7.4 is proposed:

**Proposed Modification to the Wording of 4.7.4**

4.7.4 Occupied Channel Bandwidth. (CLOSED: A.3) The occupied channel bandwidth for the PMD is 1.0 MHz wide. ~~as specified at the -20 dB points of the associated signal spectrum~~. This 1.0 MHz envelope must contain 99% of the emitted energy. ~~as measured at the ± 500 kHz frequency limits from the transmitter center frequency~~. The FCC may impose a further restriction on transmitted bandwidth requiring the 20 dB bandwidth, as measured with a spectrum analyzer and referenced to the magnitude at the center of the transmitted bandwidth, to be less than 1 MHz.

The transmitter center frequency shall be within ±25 ppm of one of the specified operating center frequenc~~y~~ies listed in section 4.7.3. The following diagram illustrates the relationship of the operating ~~channel~~ transmitter center frequency ~~(defined as $F_c$)~~ to the occupied channel bandwidth.

**(Replacement Figure)**




;Figure 4-2. Occupied Channel Bandwidth.

**Motion:**
The motion is made to adopt this proposed new wording for paragraph 4.7.4 of the Physical layer specification.

**4.7.9 Modulation**

**Discussion:**
It has become apparent that manufactures are anticipating the equivalent of a high pass function in both the receiver and transmitter baseband functions. In the transmitter, this function is embedded in the modulator. In the receiver, capacitive coupling from the discriminator may be planned. To compensate for the effect of these filtering operations on the digital waveforms, bit stuffing proposals are being considered. With an appropriate bit stuffing procedure, the high pass baseband filter functions should have only a modest effect on the transmitted wave shape. To verify this, so that interoperability is preserved, it is proposed that the modulation of the transmitted signal be monitored and specified. To this end it is proposed that an FM receiver having a flat baseband response (±1/2 dB) from 100 Hz to 500 kHz such as a Modulation analyzer be utilized to monitor the transmitted signal. With the transmitter under test set to a mid band frequency, say Channel #40, the baseband signal received by the monitoring receiver during the transmission of a pseudorandom test pattern, appropriated stuffed, would be monitored. The eye opening of the received signal shall be greater than ± 140 KHz relative to the actual center frequency of the transmitter. The test should be conducted with a known test pattern, such as a 0,1 data pattern whitened with the standard whiting algorithm. In order to ensure that the test receiver has adapted to the center frequency of the transmitter under test the test pattern shall be preceded with a 1,0 idle pattern of length T, where T is long enough to ensure that the test receiver transients are reduced to less than 5 KHz effective deviation or frequency offset before the pseudorandom test pattern begins

**Proposed change to 4.7.9:**
4.7.9 Modulation. (CLOSED: A.18) The process of moving from the frequency representing one medium symbol to the frequency representing another shall be implemented as a continuous phase frequency modulation. i~~n a manner that results in the signal on the medium being that which would have been generated by modulating an ideal voltage controlled oscillator with a baseband control signal that falls within the mask detailed in Figure 4-y. Alternatively, the time domain mask detailed in Figure 4-y could be interpreted as the range of permissible baseband waveforms that could emerge from an ideal limiter-discriminator demodulator with the transmitter and receiver coupled together through a perfect channel exhibiting a VSWR of 1.0. The signal shall be such that the boundaries of the mask detailed in Figure 4-y are not violated by any transmit symbol pattern.~~

The minimum set of requirements for a PMD to be compliant with the 802.11 FHSS PHY shall be that it is capable of operating using GFSK modulation with a modulation index of BT=0.5 and a nominal peak deviation of 160 kHz.

The PMD will accept symbols from the set {{1},{0},{tristate}}from the PLCP. The symbol {1} is encoded with a peak deviation of (+f), giving a peak transmit frequency of (Fc+f), which is greater than the carrier center frequency (Fc). The symbol {0} is encoded with a peak frequency deviation of (-f), giving a peak transmit frequency of (Fc-f). The symbol {tristate} shall be encoded as the frequency (Fc) within the tolerance specifications detailed in section 4.7.5.

As monitored with a receiver having flat baseband response, ±1/2 dB from 100 Hz to 500 kHz, the absolute deviation at the center of each bit period with a specified test pattern shall be at least 140 kHz. The test pattern shall be a maximum length data packet loaded with a 0,1 data pattern, whitened by the standard whitening algorithm and stuffed by the Phy. The test pattern shall be preceded with a 0,1 idle pattern long enough to allow transients in the test receiver to dissipate to an effective deviation of less than 5 KHz.

**Motion:**
The motion is made to adopt this proposed new wording for paragraph 4.7.9 of the Physical layer specification.

## 4.8.1 Transmit Power Levels, and
## 4.8.2 Transmit Power Level Control.

**Discussion:**
It is clear from earlier discussions in the committee that there is considerable reservation on the part of the committee to the use of an RF power level approaching the 1 Watt level allowed by the FCC. 100 mW is much less of a concern. The power limit in the current draft specification is the limit above which power control is required. Since the time of the referenced resolution, there has been no apparent progress in defining the conditions and means to control RF power. The author therefore suggests that a maximum power level be established and that the reference to power control as a requirement be eliminated.

It is the author's interpretation of the reference motions on RF power level control, A9, A10, A11, A12 and A13, that absolute power, not ERIP, is the issue.
In addition, it is suggested that 100 mW, as a nominal specification has market appeal. To that end it is recommended that there be a tolerance of 3 dB associated with a nominal 100 mW rf power limit. Therefore 200 mW, measured on a 50 Ohm basis is proposed as the maximum RF power. The transmitter will often be used with an antenna having the equivalent gain of a dipole, 2.2 dB. The author therefore suggests that a maximum ERIP of 333 mW be specified for USA markets.

**Proposed change to 4.8.1:**

4.8.1 Transmit Power Levels. (CLOSED: A.11, A.12) In addition to the requirements imposed on the transmit signal by the baseband wave shape detailed in section 4.8.9, the signal shall also exhibit the characteristic that the maximum Equivalent Radiated Power (EIRP) of the PMD, as measured in accordance with the geographically applicable regulations, shall not exceed that listed in Table 6.0. A maximum of 200 mW of antenna input power is also specified. In addition, all conformant PMD implementations shall be capable of transmitting a minimum of 1.0 mW.

| Maximum EIRP [mW] | Geography | Status |
|---|---|---|
| 333 | USA | CLOSED |
| 100 | Europe | CLOSED |
| 10 / MHz | Japan | open |

Table 16. Transmit Power Limits

**Proposed change to 4.8.2:**
4.8.2 Transmit Power Level Control (CLOSED: A.9, A.10, A.13) ~~If a conformant PMD implementation has the ability to transmit in a manner that results in the EIRP of the transmit signal exceeding the level of 100 mW, as measured by the geographically applicable regulations, at least one level of transmit power control shall be implemented. This transmit power control shall be such that the level of the emission is reduced to a level below 100 mW under the influence of said power control.~~

As an optional PMD implementation, additional power level control will consist of four (4) discrete levels that are to be determined by the manufacturer. These levels must exist between the minimum transmit power level of 1.0 mW and the maximum of ~~100~~ 200 mW.

**Motion:**
The motion is made to adopt this proposed new wording for paragraphs 4.8.1 and 4.8.2 of the Physical layer specification.

**4.8.3 Transmitter Spectral Shape**

**Discussion:**
The author suggests that specification paragraph 4.7.4 address the occupied bandwidth aspect of the transmitter specification. The principle emphases of the specification paragraph 4.8.3 is the degree to which the transmitter splatters into the alternate and remote channels. The alternate channels extend from 1.5 to 2.5 MHz from the nominal center frequency of the transmitter on either side as depicted on the diagram. With reference to doc 94/78, the intercepted power in the alternate channel should be keep below -60c dBm to be consistent with the desensitization performance or companion receivers. It is proposed that the intercepted power as measured and calculated with a spectrum analyzer be used to verify compliance. At channels spaced by 2.5 MHz or more the intercepted power measured the same way should be less than -65 dBc.

**Proposed change to 4.8.3**
(New Wording)
Conformant PMD implementations shall restrict their transmission of RF power in RF channels other the intended channel. The intercepted RF power, as measured and calculated by a commercial spectrum analyzer, shall be less than -60 dBc in the 1.5 to 2.5 MHz band removed from the operating transmit frequency on both sides of the operating center frequency For 1 MHz channels removed by 2.5 MHz or more from the carrier the intercepted power shall be less than -65 dBc.

**Motion:**

The motion is made to adopt this proposed new wording for paragraph 4.8.3 of the Physical Layer Specification

## 4.8.4 Transmit Center Frequency Tolerance

**Discussion:**
Temperature range has received little or no attention to date in the committee. In order to simplify the issue it suggested that the portable equipment and indoor applications be combined in one specification. The outdoor specification would refer to equipment permanently installed outdoors in that case the -20 °C to +55 °C is appropriate.

**Proposed change to 4.8.4**
**4.8.4 Transmit Center Frequency Tolerance. (OPEN: A.16)** An 802.11 FHSS compliant PMD shall have a transmit center frequency accuracy, as measured from $F_c$, of ±25.0 ppm. It shall maintain this stability over the following temperature ranges:

**(New Chart)**

| Minimum | Maximum | Conditions | Status |
|---|---|---|---|
| 0° C | +50° C | Portable and Indoor Equipment | **open** |
| -20° C | +55° C | Outdoors | **open** |
| | | | |

Table 17. Transmit Center Frequency Tolerance

**Motion:**
The motion is made to adopt this proposed new chart for paragraph 4.8.4 of the Physical layer specification.

## 4.9.1 Spurious Free Dynamic Range

**Discussion**
Sensitivity

In doc 93/78 by this author, a justification for a midband RF sensitivity specification of -84 dBm is presented. RF sensitivity is one of the most critical performance specifications of the standard being prepared. If the IEEE 802.11 Standard is to be successful, the receiver RF sensitivity specification must be maintained at a quality level or equipment with poor performance will degrade the reputation of the Standard.

In order to pragmatically test for compliance to the specification, it is proposed that a packet error rate test process be used rather than a idealized bit error rate, BER, test process. The $10^{-5}$ BER agreed upon as the reference for test is approximately equivalent to a packet error rate, PER, of 10 -2 if the packets are 1000 bits long. Assuming a packet length of length of 4000 bits, a typical receiver having a $10^{-5}$ BER sensitivity of -84 dBm would have 0.04 PER sensitivity of also -84 dBm.

Thus, it is proposed that at an input of -84 dBm, the PER be less than 4%, as verified by at least 100 attempts to make at error free transfer or the test packet to the receiver under test. It is also noted that there is no need for reference to a theoretical Eb/No.

In order to verify that the receiver is capable of receiving virtually error data at strong signals a test is suggested for midband performance verification only, that requires the reception of 100 sequential error free packets (based of 4000 bit packets) with the input set to -80 dBm.

Maximum input level

Previous suggestions have been made that there may be as little as 1/2 meter separation of RF LAN transceivers. Considering a nominal RF power level of +20 dBm and a separation of 1/2 meter, it is reasonable to expect a received signal level of -14 dBm. It is therefore suggested that the 4% PER specification be applied to an input level of -14 dBm.

**Proposed new wording to the specification**

4.9.1 Spurious Free Dynamic Range. (OPEN) A conformant PMD implementation must be capable of recovering a conformant PMD ~~signals~~ packets from the medium at least a 96 % success rate, with an input ~~as described in related sections,~~ whose level is between ~~-80~~ -84 dBm (defined as minimum sensitivity) and ~~-20~~ -14 dBm (defined as maximum allowable input level). ~~The conformant PMD signal must maintain an $E_b/N_o$ of 16.0 dB in the presence of Gaussian white noise at a BER of greater than or equal to $10^{-5}$.~~ For inputs between -82 dBm and -20 dBm the success rate should be in excess of 99 %.

**Motion:**

The motion is made to adopt this proposed new wording for paragraph 4.9.1 of the Physical layer specification.

**4.9.2 Selectivity.**

**Discussion**

In doc 94/78, the issue of selectivity is discussed in detail. In that submission, the conclusion is drawn that the selectivity protection in the alternate channel should be 40 dB and in more removed channels, 45 dB. The desired signal for these measurements shall be 3 dB above sensitivity.

**Proposed new wording to the specification**

4.9.2 Selectivity. (OPEN) A conformant PMD implementation must be capable of recovering a conformant PMD signal from the medium, as described in related sections, when a signal is offset from the center frequency ($F_c$) ~~by greater~~ than 2.0 MHz or more and has a power level that is ~~45~~ 40 dB higher than that of the desired signal.

Conformance to this section is measured by inputting an in-channel signal at a level that provides a PER of 4 %. ~~BER of $10^{-5}$~~. This signal is then increased in level by ~~1.0~~ 3.0 dB. Simultaneously, an alternate channel signal with the same modulation characteristics, defined as $F_c \pm 2.0$ MHz, is increased in level until the resultant PER of 4%. ~~BER is $10^{-5}$~~. The difference between the desired and undesired signal levels must be greater than ~~45~~ 40 dB. This measurement is performed in a AWGN channel.

The measurement shall also be done at Fc ± 3 MHz and protection shall be greater than 45 dB

**Motion:**
The motion is made to adopt this proposed new wording for paragraph 4.9.2 of the Physical layer specification.

## 4.9.3 Channel BER.

**Discussion**
In light on the specification on sensitivity this specification is not required

**Proposed change to 4.9.3**
~~A conformant PMD implementation must provide a channel BER of at least $10^{-5}$ at an $E_b/N_o$ of 16.0 dB in an AWGN channel.~~

**Motion**
It is moved that this specification be eliminated

## 4.9.4 Receive Center Frequency Tolerance.

Discussion
See 4.8.4 above
Proposed new wording

An 802.11 FHSS compliant PMD shall have a receive center frequency accuracy, as measured from $F_c$, of ±25.0 ppm. It shall maintain this stability over the following temperature ranges:

**(New Chart)**

| Minimum | Maximum | Conditions | Status |
|---|---|---|---|
| $0^o$ C | $+50^o$ C | Portable and Indoor Equipment | **open** |
| $-20^o$ C | $+55^o$ C | Outdoors | **open** |
| | | | |

Motion
It is moved that the above change in the chart be made to the specification.