IEEE P802.11
Wireless Access Method and Physical Layer Specifications

Title: **Proposed changes to D1 Section 12 based on Ballot Changes**

Authors:

Barry A. Dobyns
Photonics Corporation
2940 North First Street
San Jose, CA 95134, USA
Voice: 408-944-7930
FAX: 408-944-7950
EMail: 76527,266

Tom Baumgartner
Spectrix Corporation
906 University Pl
Evanston, IL 60201
Voice: 708-491-4534
Fax: 708-467-1094

Adriano Moreira
University of Aveiro
3800 Aveiro, Portugal
Tel: +351 34 381937
Fax: +351 34 381941
adriano@ua.pt

Hirohisa Wakai
Sharp
1385 Shattuck Av #102
Berkeley, CA 94709
Voice: 510 644 9267
Fax: 510 644 1126
wakai@sharp.co.jp

Abstract:

What's Wrong:
Some people inexplicably voted against the IR PHY Section with comments.

How To Fix It:
Accept the corrected Section 12 text as shown below

Motions:
Resolved that the text in document 802.11-95/46 be incorporated into the next draft of the standard as section 12 as shown.

IR PHY VOTE 3-0-0

12. ~~Baseband~~ Infrared Physical Layer Specification

12.1. Introduction

This section describes the physical layer for the ~~Baseband~~ Infrared system. The ~~Baseband~~ IR PHY uses near-visible light in the 850 nanometer to 950 nanometer range for signaling. This is similar to the spectral usage of both common consumer devices such as infrared remote controls, as well as other data communications equipment such as IrDA (Infrared Data Association) devices.

However, unlike many other infrared devices the ~~Baseband~~ IR PHY is not directed. That is, the receiver and transmitter do not have to be aimed at each other and do not need a clear line-of-sight. This permits the construction of a true LAN system, whereas with an aimed system, it would be difficult or impossible to install a LAN because of physical constraints.

A pair of conformant ~~Baseband~~ Infrared devices would be able to communicate in a typical environment at a range up to about ten meters. The standard allows conformant devices to have more sensitive receivers, and this may increase range up to about twenty meters.

The ~~Baseband~~ Infrared PHY relies on both reflected infrared energy as well as line-of-sight infrared energy for communications. Most designs anticipate that ALL of the energy at the receiver is reflected energy. This reliance on reflected infrared energy is called "Diffuse Infrared" transmission.

The standard specifies the transmitter and receiver in such a way to *ensure* ~~insure~~ that a conformant design will operate well in most environments where there is no line-of-sight path from the transmitter to the receiver. However, in an environment which has few or no reflecting surfaces, and where there is no line-of-sight, ~~performance of~~ a ~~Baseband~~ Infrared PHY system may suffer *reduced range*.

The Infrared PHY will operate only in indoor environments. Infrared radiation does not pass through walls, and is significantly attenuated passing through most exterior windows. This characteristic can be used to "contain" a ~~Baseband~~ Infrared PHY in a single physical room, like a classroom or conference room. Different LANs using the ~~Baseband~~ Infrared PHY can operate in adjacent rooms separated only by a wall without interference, and without the possibility of eavesdropping.

At the time of this standard's preparation, the only known regulatory standards which apply to the use of infrared radiation are safety regulations, such as IEC 825-1 and ANSI Z - 136.1. While a conformant ~~Baseband~~ Infrared PHY device can be designed in a way to also comply with these safety standards, conformance with this standard does not *ensure* ~~insure~~ conformance with other standards.

Worldwide, there are currently no frequency allocation or bandwidth allocation regulatory restrictions on infrared emissions.

Emitter (typically LED) and detector (typically Pin-Diode) devices for infrared communications are relatively inexpensive at the infrared wavelengths specified in the ~~Baseband~~ Infrared PHY, and at the electrical operating frequencies required by this PHY.

While many other devices in common use also use infrared emissions in the same optical band, these devices usually transmit infrared intermittently and do not interfere with the proper operation of a compliant ~~Baseband~~ Infrared PHY. If such a device does interfere, by transmitting continuously and with a very strong signal, it can be physically isolated (placing it in a different room ~~is usually sufficient~~) from the 802.11 LAN.

12.1.1. Scope

This section describes the physical layer services provided *to* ~~by~~ the 802.11 wireless LAN MAC *by* ~~for~~ the ~~Baseband~~ Infrared (IR) system. The ~~Baseband~~ IR PHY layer consists of two protocol functions as follows:

a) A physical layer convergence function which adapts the capabilities of the physical medium dependent system into the Physical Layer service. This function is supported by the Physical Layer Convergence Procedure (PLCP) which defines a method of mapping the 802.11 MAC layer Protocol Data Units (MPDU) into a framing format suitable for sending and receiving user data and management information between two or more *stations* ~~nodes~~ using the associated physical medium dependent system.

b) A Physical Medium Dependent (PMD) system whose function defines the characteristics of, and method of transmitting and receiving data via wireless media between two or more *stations* ~~nodes~~.

Each physical medium dependent sublayer for the ~~Baseband~~ IR PMD may require the definition of a unique PLCP. If the PMD sublayer already provides the defined Physical Layer services, the physical layer convergence function *may* ~~might~~ be null.

12.1.2. ~~Baseband~~ IR Physical Layer Functions

The ~~Baseband~~ IR physical layer contains three functional entities: the physical medium dependent function, the physical layer convergence function, and the layer management function. Each of these functions is described in detail in the following subsections.

The ~~Baseband~~ IR Physical Layer service is provided to the Media Access Control entity at the node through a Service Access Point (SAP) as described in Section 8, Physical Service Specification. For a visual guide to the relationship of the ~~Baseband~~ IR Physical Layer to the remainder of a system, refer to figure 2-11, *Portion of the ISO Basic Reference Model Covered in this Standard.*

12.1.2.1. Physical Layer Convergence Procedure Sublayer

In order to allow the 802.11 MAC to operate with minimum dependence on the PMD sublayer, a physical layer convergence sublayer is defined. This function simplifies the physical layer service interface to the 802.11 MAC services. The PHY specific preamble is normally associated with this convergence layer.

12.1.2.2. Physical Medium Dependent Sublayer

The physical medium dependent sublayer provides a clear channel assessment mechanism, transmission mechanism and reception mechanism which are used by the MAC via the PLCP to send or receive data between two or more *stations* ~~nodes~~.

12.1.2.3. Physical Layer Management Entity (LME)

The Physical LME performs management of the local Physical Layer Functions in conjunction with the MAC Management entity.

~~12.1.3. Definitions~~

~~This section defines the terms used in this standard. Words in *italics* indicate terms that are defined elsewhere in the lists of definitions~~

~~12.1.4. Acronyms~~

~~CRC~~	~~—~~	~~Cyclic Redundancy Check~~
~~DCLA~~	~~—~~	~~DC Level Adjustment~~
~~FCS~~	~~—~~	~~Frame Check Sequence~~
~~IR~~	~~—~~	~~Infrared~~
~~IrDA~~	~~—~~	~~Infrared Data Association~~
~~LME~~	~~—~~	~~Layer Management Entity~~
~~MAC~~	~~—~~	~~Media Access Control~~
~~MPDU~~	~~—~~	~~MAC Protocol Data Unit~~
~~PDU~~	~~—~~	~~Protocol Data Unit~~
~~PHY_SAP~~	~~—~~	~~Physical Layer Service Access Point~~
~~PLCP~~	~~—~~	~~Physical Layer Convergence Procedure~~
~~PMD~~	~~—~~	~~Physical Medium Dependent~~
~~PMD_SAP~~	~~—~~	~~Physical Medium Dependent Service Access Point~~
~~PPM~~	~~—~~	~~Pulse Position Modulation~~
~~SAP~~	~~—~~	~~Service Access Point~~

12.1.5. Service Specification Method and Notation

The models represented by figures and state diagrams are intended as the illustrations of functions provided. It is important to distinguish between a model and a real implementation. The models are optimized for simplicity and clarity of presentation, the actual method of implementation is left to the discretion of the 802.11 ~~Baseband~~ IR PHY compliant developer. Conformance to the standard is not dependent on following the model, and an implementation which follows the model closely may not be conformant.

The service of layer or sublayer is a set of capabilities that it offers to a user in the next higher layer (or sublayer). Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition is independent of any particular implementation. In particular, the PHY_SAP operations are defined and described as instantaneous, however, this may be difficult to achieve in an implementation.

12.2. ~~Baseband~~ IR Physical Layer Convergence Procedure Sublayer

While the Physical Layer Convergence Procedure (PLCP) sublayer and the Physical Medium Dependent (PMD) sublayer are described separately, the separation and distinction between these sublayers is artificial, and is not meant to imply that the implementation must separate these functions. This distinction is made primarily to provide a point of reference from which to describe certain functional components and aspects of the PMD. The functions of the Physical Layer Convergence Procedure can be subsumed by a Physical Medium Dependent sublayer: In this case, the PMD will incorporate the PHY_SAP as it's interface, and will not offer a PMD_SAP.

12.2.1. Introduction

This section provides a convergence procedure in which MPDUs are converted to and from PDUs. During transmission, the MPDU *(PSDU)* is *prepended* ~~appended~~ with a PLCP Preamble and PLCP Header to create the PDU. At the receiver, the PLCP Preamble is processed and the internal data fields are processed to aid in demodulation and delivery of the MPDU *(PSDU)*.

12.2.2. Physical Layer Convergence Procedure Frame Format

Figure 12-1 shows the format for the PDU including the PLCP Preamble, the PLCP Header and the *PSDU* ~~MPDU~~. The PLCP Preamble contains the following fields: Synchronization (SYNC) and Start Frame Delimiter (SFD). The PLCP Header contains the following fields: Data Rate (DR), DC Level Adjustment (DCLA), Length (LENGTH) and CRC. Each of these fields will be described in detail in section 12.2.4.

PLCP Preamble		PLCP Header				PSDU
SYNC	SFD	DR	DCLA	LENGTH	CRC	
57-73 slots	4 slots	3 slots	32 slots	16 bits	16 bits	variable number of octets

Figure 12-1: *PDU* ~~PLCP~~ Frame Format

12.2.3. PLCP Modulation and Rate Change

The PLCP Preamble shall be transmitted using the basic pulse defined in section 12.3.3.2. The *PSDU* ~~MPDU~~, LENGTH and CRC fields are transmitted using Pulse Position Modulation (PPM). PPM maps *bits in the octet* ~~words~~ into symbols: a *16-PPM maps four bits into a 16 position symbol, and 4-PPM maps two bits into a 4 position symbol.* ~~word with n bits is mapped into one of the L=2^n positions of a symbol (L-PPM).~~ The basic L-PPM time unit is the slot. A slot corresponds to one of the L positions of a symbol and has a 250 ns duration. The *PSDU* ~~MPDU~~, LENGTH and CRC fields are transmitted in one of two bit rates: *1* Mbps and 2 Mbps. The Data Rate field indicates the data rate which will be used to transmit the *PSDU* ~~MPDU~~, LENGTH and CRC fields. The 1 MBPS data rate uses 16-PPM (Basic Access Rate) and the 2 MBPS data rate uses 4-PPM (Enhanced Access Rate). The transmitter and receiver will initiate the modulation or demodulation indicated by the DR field starting with the first 4 bits in 16-PPM or 2 bits in 4-PPM of the LENGTH field. The *PSDU* ~~MPDU~~ transmission rate is set by the RATE parameter in PHY_DATA.request primitive specifying START-OF-ACTIVITY. Any conformant ~~Baseband~~ IR PHY shall be capable of receiving at 1 MBPS and 2 MBPS. Transmission at 2 MBPS is optional.

A PHY_DATA.request which specifies a data rate which is not supported by an PHY instance will cause the PHY to indicate an error to it's MAC instance. A PHY is not permitted in any circumstance to transmit at a different rate than the requested rate.

12.2.4. PLCP Field Definitions

12.2.4.1. PLCP Synchronization (SYNC)

The SYNC field consists of a sequence of alternated presence and absence of a pulse in consecutive slots. The SYNC field has a minimum length of 57 *L-PPM* slots and a maximum length of 73 *L-PPM* slots and shall terminate with *the absence of a pulse in the last* ~~an empty~~ slot. This field is provided so that the receiver can perform clock recovery (slot synchronization), automatic gain control (optional), signal-to-noise ratio estimation (optional) and diversity selection (optional).

The SYNC field is not modulated using L-PPM, but instead consists of transitions in L-PPM slots which would otherwise constitute an illegal symbol.

12.2.4.2. PLCP Start Frame Delimiter (SFD)

The SFD field length is 4 *L-PPM* slots and consists of the binary sequence 1001, *where 1 indicates a pulse in the L-PPM slot and 0 indicates no pulse in the L-PPM slot.* The left most bit *shall be* ~~is~~ transmitted first. The SFD field is provided to indicate the start of the PLCP Preamble and to perform bit and symbol synchronization.

The SFD field is not modulated using L-PPM, but instead consists of transitions in L-PPM slots which would otherwise constitute an illegal symbol.

12.2.4.3. PLCP Data Rate (DR)

The DR field indicates to the PHY the data rate *that shall* ~~which will~~ be used for the transmission or reception of the *PSDU* ~~MPDU~~, LENGTH and CRC fields. The transmitted value *shall be* ~~is~~ provided by the PHY_DATA.request primitive specifying START_OF_ACTIVITY as described in section 8. The DR field has a length of 3 *L-PPM* slots. The left most bit, as shown below, *shall be* ~~is~~ transmitted first. The ~~Baseband IR~~ *Infrared* PHY currently supports two data rates defined by the *slot pattern* ~~following~~ *shown for the three L-PPM slots following the SFD, where 1 indicates a pulse in the L-PPM slot and 0 indicates no pulse in the L-PPM slot.* ~~binary words~~:

1 MBPS:	000
2 MBPS:	001

The DR field is not modulated using L-PPM, but instead consists of transitions in L-PPM slots which would otherwise constitute an illegal symbol.

~~This field allows for the future introduction of a maximum of 8 different data rates.~~

12.2.4.4. PLCP DC Level Adjustment (DCLA)

The DCLA field is required to allow the receiver to stabilize the DC level after the SYNC , SFD and DR fields. The left most bit, as shown below, *shall be* ~~is~~ transmitted first. The length of the DCLA field is 32 *L-PPM* slots and consists of the *contents shown, where 1 indicates a pulse in the L-PPM slot and 0 indicates no pulse in the L-PPM slot* ~~binary words~~:

1 MBPS:	00000000100000000000000010000000
2 MBPS:	00100010001000100010001000100010

The DCLA field is not modulated using L-PPM, but instead consists of transitions in L-PPM slots which would otherwise constitute an illegal symbol.

12.2.4.5. PLCP LENGTH

The LENGTH field is an unsigned 16 bit integer which indicates the number of octets to be transmitted in the PSDU. The transmitted value *shall be* ~~is~~ provided by the PHY_DATA.request primitive specifying Start_of_Activity as described in section 8. The LSB (least significant bit) shall be transmitted first in time. This field is *modulated and* sent in L-PPM format. This field is protected by the CRC~~16 Frame Check Sequence~~ described in *the* next section.

12.2.4.6. PLCP CRC

The LENGTH field shall be protected by a *16-bit CRC-CCITT* ~~CCITT CRC16 FCS (Frame Check Sequence)~~. The *CRC-CCITT* ~~CRC16 FCS~~ is the ones compliment of the remainder generated by the *modulo* ~~module~~ 2 division of the LENGTH field by the polynomial:

$$x^{16}+x^{12}+x^{5}+1$$

The protected bits will be processed in transmit order. The LSB (least significant bit) *of the 16-bit CRC-CCITT* shall be transmitted first in time. This field *shall be* ~~is~~ *modulated and* sent in L-PPM format. All *CRC-CCITT* ~~FCS~~ calculations shall be made prior to L-PPM encoding on transmission and after L-PPM decoding on reception.

12.2.4.7. *PSDU* ~~MPDU~~ Field

This field is composed of a variable number of octets. The minimum is 0 (zero) and the maximum is 2500. The LSB (least significant bit) of each octet shall be transmitted first in time. All the octets of this field *shall be* ~~are~~ *modulated and* sent in L-PPM format.

12.2.5. PLCP Procedures

12.2.5.1. PLCP Transmit Procedure

All commands issued by the MAC require PHY_DATA.confirm primitives to be issued by the PHY. The PHY_DATA.confirm primitives provide flow control between the MAC and the PHY.

The steps below are the transmit procedure:

a) Based on the status of CCA the MAC will determine if the channel is clear.
b) If the channel is clear, transmission of the *PSDU* ~~MPDU~~ is initiated by a PHY_DATA.request class=*Start_of_Activity* ~~Start_of_Data~~ with DATA parameters LENGTH and RATE.
c) The PHY entity will immediately initiate transmission of the PLCP preamble and PLCP header based on the LENGTH and RATE parameters passed in the PHY_DATA.request class=*Start_of_Activity* ~~Start_of_Data~~ . Once the PLCP preamble and PLCP header transmission is completed the PHY entity issues a PHY_DATA.confirm.
d) *Each octet of the PSDU is passed from* ~~Data is then exchanged between~~ the MAC *to* ~~and~~ the PHY by a series of PHY_DATA.request class=DATA. Each PHY_DATA.request must be answered by the PHY with a PHY_DATA.confirm before the next request is made.
e) At the PHY layer each *PSDU* octet is divided into symbols (2 or 4 bits). The symbols are *modulated using L-PPM and* transmitted into the medium.
f) Transmission is terminated by the MAC through the primitive PHY_DATA.request class=End_of_Data*_and_Activity*. The PHY indicates the end of the transmission with a PHY_DATA.Confirm.

12.2.5.2. PLCP Receive Procedure

The steps below are the receive procedure:

a) CCA is provided to the MAC via the PHY_DATA.indicate class=Start_of_Activity and the PHY_DATA.Indicate class=End_of_Activity. *When PHY senses activity on the medium it* *indicates that the medium is busy with a PHY_DATA.Indicate class=Start_of_Activity. This will normally occur during the SYNC field of the PLCP preamble.* ~~1Reception is initiated by a PHY_DATA.Indicate class=Start_of_Activity indicating that the medium is busy. This will occur during the SYNC field of the PLCP preamble.~~

b) The PHY entity will then begin searching for the SFD field. Once the SFD field is detected the PHY entity will receive the PLCP header. After receiving the DR and DCLA fields the CRC processing is initiated and LENGTH field is received. The change indicated in the DR field is initiated with the first symbol of the LENGTH field. The *CRC-CCITT* ~~CRC16 FCS~~ will be processed.

c) If the *CRC-CCITT* ~~CRC16 FCS~~ check fails or no match is found for DR field then NO PHY_DATA.Indicate class=Start_of_Data will be issued. When the medium is again free, the PHY will issue PHY_DATA.Indicate class=End_of_Activity.

d) If the PLCP preamble and PLCP header reception is successful, the PHY sends a PHY_DATA.Indicate class=*Start_of_Data* ~~Start Of Data~~, including the parameters RATE and LENGTH.
A PHY must guarantee that the length reported to it's MAC in the RXVECTOR of PHY_DATA.Indicate class=Start_of_Data is equal to the length sent from the peer MAC to the peer PHY entity in the TXVECTOR of PHY_DATA.request class=Start_of_Data.

e) The received *PSDU* ~~MPDU~~ L-PPM symbols are assembled into octets and presented to the MAC using a series of PHY_DATA.Indicate class=DATA.. The PHY proceeds with *PSDU* ~~MPDU~~ reception.

f) Reception is terminated after the reception of the final symbol of the last *PSDU* ~~MPDU~~ octet indicated by the PLCP header LENGTH field. After the PHY_DATA.Indicate class=Data for that octet is issued, the PHY will issue PHY_DATA.Indicate class=End_of_Data.

g) After the PHY_DATA.Indicate class=End_of_Data, when the medium is no longer busy, the PHY will issue PHY_DATA.Indicate class=End_of_Activity. .

12.2.5.3. CCA Procedure

CCA is provided to the MAC via the PHY_DATA.Indicate class=Start_of_Activity and the PHY_DATA.Indicate class=End_of_Activity

The steps below are the CCA procedure:

a) When the PHY senses activity on the medium a PHY_DATA.Indicate class=Start_of_Activity is issued. This will normally occur during the SYNC field of the PLCP preamble.

b) When the PHY senses the medium is free, a PHY_DATA.Indicate class=End_of_Activity is issued.

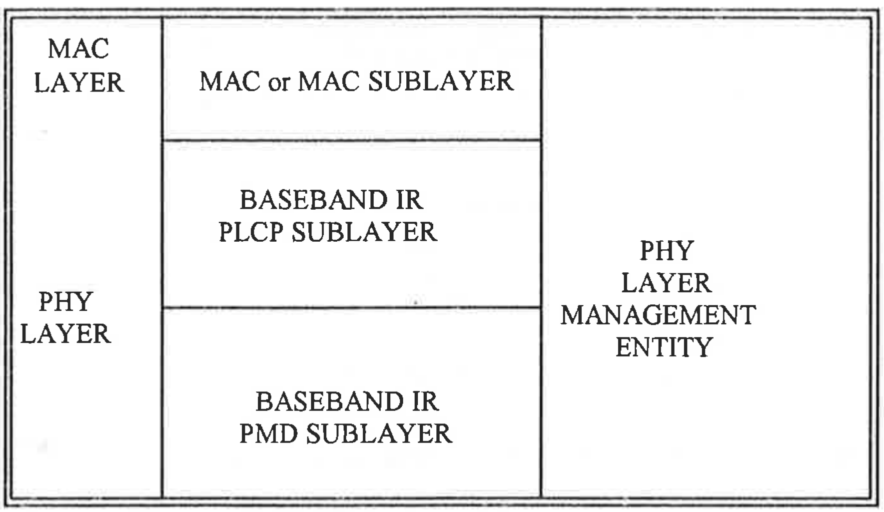
c) At any time, the MAC may issue a PHY_DATA.request class=End_of_Activity, which will reset the PHY's internal CCA detection mechanism to the medium not busy (free) state. The PHY_DATA.confirm to this request shall indicate that the PHY now believes the medium is free.

12.3. ~~Baseband~~ IR Physical Medium Dependent Sublayer

The ~~Baseband~~ IR Physical Medium Dependent Sublayer does not define PMD Service Access Primitives. The mechanism for communications between the PLCP and PMD sublayers, as well as the distinction between these two sublayers, if any, are left to the implementors. In particular, it is possible to design and implement in a conformant way a single sublayer which subsumes the functions of both the PLCP and PMD, presenting only the PHY_SAP.

12.3.1. Introduction

This section describes the PMD functional, electrical, and optical characteristics required for interoperability of implementations conforming to this specification. The relationship of this specification to the entire ~~Baseband~~ IR PHY Layer is shown in figure *2-11 in section 2.9 Reference Model.* ~~12-2.~~



~~**Figure 12-2: PMD Layer Reference Model**~~

~~The Baseband IR Physical Medium Dependent Sublayer provides the actual means by which data is transmitted or received from the media.~~

12.3.2. PMD Operating Specifications General

The following sections provide general specifications for the ~~Baseband~~ IR Physical Medium Dependent sublayer. These specifications apply to both the receive and transmit functions and general operation of a compliant ~~Baseband~~ IR PHY.

12.3.2.1. Modulation and Channel Data Rates

Two modulation formats and data rates are specified for the ~~Baseband~~ IR PHY: a Basic Access Rate and an Enhanced Access Rate. The Basic Access Rate is based on 1 MBPS 16-PPM modulation. The 16-PPM encoding is specified in Table 12-1. Each group of 4 data bits is mapped in one of 16-PPM symbols. The Enhanced Access Rate is based on 2 MBPS 4-PPM. The 4-PPM encoding is specified in Table 12-2. Each group of 2 data bits is mapped into one of 4-PPM symbols. Transmission into the medium is from left to right, as shown below.

The data in these tables has been arranged (gray coded) so that a single out-of-position-by-one error in the medium, caused, for example, by intersymbol interference, results in only a single bit error in the received data, rather than a multiple bit error.

Data	16-PPM Symbol
0000	0000000000000001
0001	0000000000000010
0011	0000000000000100
0010	0000000000001000
0110	0000000000010000
0111	0000000000100000
0101	0000000001000000
0100	0000000010000000
1100	0000000100000000
1101	0000001000000000
1111	0000010000000000
1110	0000100000000000
1010	0001000000000000
1011	0010000000000000
1001	0100000000000000
1000	1000000000000000

Table 12-1: MBPS 16-PPM Basic Rate Mapping

Data	4-PPM Symbol
00	0001
01	0010
11	0100
10	1000

Table 12-2: MBPS 4-PPM Enhanced Rate Mapping

12.3.2.2. Octet Partition and PPM symbol generation procedure

Since PPM is a block modulation method, with the block size less than a full octet, octets have to be partitioned prior to modulation (mapping into PPM symbols).

Octet partition depends on the PPM order being used.

Assume an octet is formed by eight bits numbered *7 6 5 4 3 2 1 0* ~~0 1 2 3 4 5 6 7~~, where bit 0 is the LSB (least significant bit). Partition the octet as follows:

For 16-PPM, create two PPM symbols:
the symbol using bits *3 2 1 0* ~~0 1 2 3~~ transmitted onto the medium first
the symbol using bits *7 6 5 4* ~~4 5 6 7~~ transmitted onto the medium last

For 4-PPM, create four PPM symbols:
the symbol using bits *1 0* ~~0 1~~ transmitted onto the medium first
the symbol using bits *3 2* ~~2 3~~ transmitted onto the medium second
the symbol using bits *5 4* ~~4 5~~ transmitted onto the medium third
the symbol using bits *7 6* ~~6 7~~ transmitted onto the medium last

12.3.2.3. *Operating Environment*

The Infrared PHY will operate only in indoor environments. Infrared PHY interfaces can not be exposed to direct sun light. The Infrared PHY relies on reflected infrared energy and does not require a line-of-sight between emitter and receiver in order to work properly. The range and bit-error-rate of the system may vary with the geometry of the environment and with the natural and artificial illumination conditions.

12.3.2.4. *Operating Temperature Range*

The temperature range for full operation compliance with the Infrared PHY is specified as 0 to 40 degrees centigrade.

12.3.3. PMD Transmit Specifications

The following sections describe the transmit functions and parameters associated with the Physical Medium Dependent sublayer.

12.3.3.1. Transmitted Peak Optical Power

The peak optical power of an emitted pulse shall be 2 W ± 20% averaged over the pulse width.

12.3.3.2. Basic Pulse Shape and Parameters

The basic pulse width measured between the 50% amplitude points, shall be 250 ns ± 10 ns. The pulse rise time, measured between the 10% and 90% amplitude points, shall be lower than or equal to 40 ns. The pulse fall time, measured between the 10% and 90% amplitude points, shall be lower than or equal to 40 ns. The *edge* ~~pulse~~ jitter, defined as the absolute deviation in time of the *edge* ~~pulse~~ from its correct position, shall be lower than or equal to 10 ns.

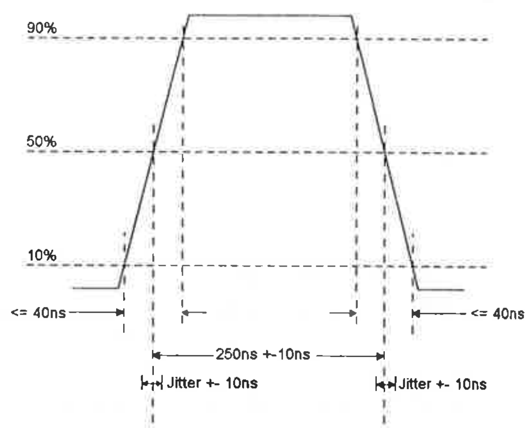


Figure 12-3: Basic Pulse Shape

12.3.3.3. Emitter Radiation Pattern Mask

The emitter radiation pattern mask is defined in table 12-3. Position the conformant device in its recommended attitude. Define the conformant device axis as the axis passing through the emitter center and having the direction of the vertical from the floor. The mask represents the irradiance normalized to the *total peak* ~~average~~ emitted power, as a function of the angle between the conformant device axis and the axis from the emitter center to the test receiver center (declination angle). The distance between emitter and test receiver is 1 meter. The test receiver normal is always aimed at the emitter center. The azimuth angle is a rotation angle on the conformant device axis.

DECLINATION ANGLE	NORMALIZED IRRADIANCE
$\alpha \leq 60°$	$> 3.5e-6$
$\alpha \leq 29°$	$\leq 2.2e-5$
$29° < \alpha \leq 43°$	$\leq$ -1.06e-4 + (0.44e-5) α
$43° < \alpha \leq 57°$	$\leq$ 1.15e-4 - (7.1e-7) α
$57° < \alpha \leq 74°$	$\leq$ 2.98e-4 - (3.9e-6) α
$74° < \alpha \leq 90°$	$\leq$ 4.05e-5 - (4.5e-7) α

Table 12-3: Definition of the Emitter Radiation Pattern Mask

A device is conformant if for any azimuth angle its radiation pattern as a function of declination angle falls within the pattern mask.

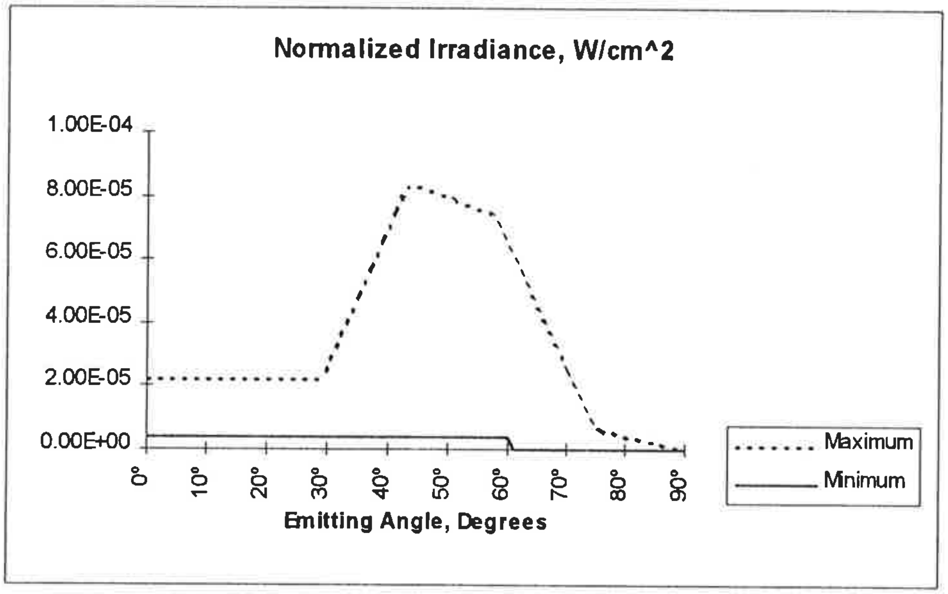


Figure 12-4: Emitter radiation pattern mask.

Other radiation patterns may be added at a later time.

12.3.3.4. Optical Emitter Peak Wavelength

The optical emitter peak wavelength shall be between 850 and 950 nm.

12.3.3.5. Transmit Spectrum Mask

Define the transmit spectrum of a transmitter as the Fourier Transform, or equivalent, of a voltage (or current) signal whose amplitude, as a function of time, is proportional to the transmitted optical power.

The transmit spectrum of a conformant transmitter shall be 20 dB below its maximum for all frequencies above 15 MHz. The transmit spectrum mask is shown in figure 12-5.

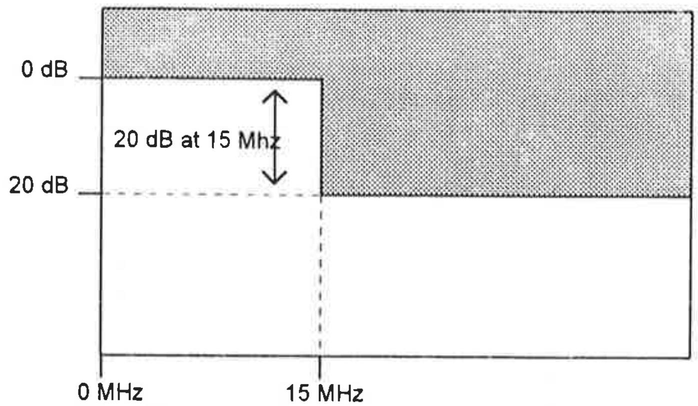


Figure 12-5: Transmit spectrum mask.

12.3.4. PMD Receiver Specifications

The following sections describe the receive functions and parameters associated with the Physical Medium Dependent sublayer.

12.3.4.1. Receiver Sensitivity

The Receiver Sensitivity defined as the minimum irradiance (in mW/cm^2) at the photodetector plane required for a FER *(Frame Error Rate)* of $4x10^{-5}$ with an *PSDU* ~~MPDU~~ of 512 octets and with *an unmodulated* background IR source between 800 nm and 1000 nm with a level of 0.1 mW/cm^2 , shall be:

1 MBPS: $2.x10^{-5}mW/cm^2$
2 MBPS: $8.x10^{-5}mW/cm^2$

12.3.4.2. Receiver Dynamic Range

The receiver dynamic range, defined as the ratio between the maximum and minimum irradiance at the plane normal to the receiver axis that assures a FER lower than or equal to $4x10^{-5}$ with an *PSDU* ~~MPDU~~ of 512 octets and with *an unmodulated* background IR source between 800 nm and 1000 nm with a level of 0.1 mW/cm^2 , shall be greater or equal to 30 dB.

12.3.4.3. Receiver Field-of-View (FOV)

Define the receiver axis as the direction of incidence of the optical signal at which the received optical power is maximum.

The received optical power shall be greater than the values given in the table below, at the angles indicated, where "Angle of Incidence" is the angle of incidence of the optical signal relative to the receiver axis, and "Received Power" is the received optical power as a percentage of that measured at the receiver axis.

ANGLE OF INCIDENCE	*RECEIVED POWER*
$\alpha \leq 20°$	$\geq 65\%$
$\alpha \leq 40°$	$\geq 55\%$
$\alpha \leq 60°$	$\geq 35\%$
$\alpha \leq 80°$	$\geq 10\%$

Table 12-4: Definition of the Receiver Field Of View

~~Define the receiver FOV as twice the angle measured between the receiver axis and the direction of incidence at which the received optical power is 50% of the received optical power on the receiver axis. For incident angles smaller than half the FOV, the received optical power should always be higher than 50% of the received power on the receiver axis.~~

~~The receiver FOV of a conformant receiver shall be greater than or equal to 90°~~

12.3.5. Clear Channel Assessment, Carrier Detect and Energy Detect Definitions

12.3.5.1. Clear Channel Assessment

Clear Channel Assessment (CCA) *shall* ~~will~~ be asserted “CLEAR” by the PHY when the Carrier Detect Signal (CS) and the Energy Detect Signal (ED) are both false, or when ED has been continuously asserted for a period of time defined by the product of CCA_WATCHDOG_TIMER and CCA_WATCHDOG_COUNT without CS becoming active. When either CS or ED go true, CCA is indicated as “BUSY” to the MAC via the primitive PHY_DATA.Indicate class=Start_of_Activity .

Normally, CCA will be held “BUSY” throughout the period of the PLCP Header. After receiving the last PLCP bit and the first data octet, the PHY *shall* ~~will~~ signal PHY_DATA.Indicate class=Start_of_DATA with the parameters LENGTH and RATE. CCA *shall* ~~will~~ be held “BUSY” until the number of octets specified in the decoded PLCP Header are received. At that time the PHY *shall* ~~will~~ signal PHY_DATA.Indicate class=End_of_Data. *The CCA may remain "BUSY" after the end of data if some form of energy is still being detected. The PHY will signal PHY_DATA.Indicate class=End_of_Activity only when the CCA goes "CLEAR".* ~~If CCA remains “BUSY”, indicating some form of the PHY will signal PHY_DATA.Indicate class=End_of_Activity only when CCA goes “CLEAR”.~~

The transition of CCA from "BUSY" to "CLEAR" is indicated to the MAC via the primitive PHY_DATA.Indicate, class=End_of_Activity.

If CS and ED go false before the PHY signals PHY_DATA.Indicate class=DATA, CCA is set to “CLEAR” and <u>immediately</u> signaled to the MAC via PHY_DATA.Indicate class=End_of_Activity. If CS and ED go false after the PHY has signaled PHY_DATA.Indicate class=DATA implying that the PLCP Header has been properly decoded, then the PHY *shall* ~~will~~ not signal a change in state of CCA until the proper interval has passed for the number of bytes indicated by the received PLCP LENGTH. At that time, the PHY *shall* ~~will~~ signal PHY_DATA.indicate class=End_of_Data. followed by PHY_DATA.indicate class= End_of_Activity.

The transition of CCA from “CLEAR” to “BUSY” resets the timer and counter associated with CCA_WATCHDOG_TIMER and CCA_WATCHDOG_COUNT, respectively.

CCA_WATCHDOG_TIMER and CCA_WATCHDOG_COUNT are parameters available via MIB table entries and can be read and set via the LME.

Rise and fall times of CCA relative to the OR'ing of the CS and ED signals *shall* ~~will~~ be less than 30 nanoseconds. CS and ED are both internal signals to the PHY and are not available directly to the MAC, nor are they defined at any exposed interface.

12.3.5.2. Carrier Detect Signal

The Carrier Detect Signal (CS) is asserted by the PHY when it detects and locks on to an incoming PLCP Preamble signal. This signal is not directly available to the MAC. Conforming PHY are required to assert this condition within the first 12 microseconds of signal reception, at *the minimum* ~~a~~ signal level equal to the receiver sensitivity specified in 12.3.3.7 "Receiver Sensitivity", with a background IR level as specified in 12.3.3.7 "Receiver Sensitivity".

The Carrier Detect Signal (CS) is de-asserted by the PHY when the receiving conformant device loses carrier lock.

Note that the 12 microseconds specification is somewhat less than the minimum length of PLCP SYNC interval which is 14.25 usec.

The Carrier Detect Signal (CS) shall operate independently of Energy Detect (ED) and shall not require a prior ED before the acquisition and assertion of CS. This permits reception of signals at the minimum signal level specified in 12.3.3.7 "Receiver Sensitivity", even though these signals fall below the ED level.

This signal is not directly available to the MAC.

12.3.5.3. Energy Detect

The Energy Detection Signal (ED) is set true when IR energy variations in the band between 1 MHz and 10 MHz exceed 0.001 mW/cm^2.

The Energy Detect (ED) shall operate independently of Carrier Detect Signal(CS). ED shall not be asserted at the minimum signal level specified in 12.3.3.7 "Receiver Sensitivity", which is below the level specified here..

This signal is not directly available to the MAC.

12.4. PHY Managed Objects

PHY Managed objects have default values, or allowed values which are PHY dependent. This section describes those values, and further specifies whether they are permitted to vary from implementation to implementation.

This section does not provide the definition of the MIB objects, but only provides the Infrared PHY - specific values for the MIB Objects whose definitions and ASN.1 are in Section 9 of this Standard.

***PHY* MIB Object**	**Default Value**	**Operational Semantics**	**Operational Behavior**
aCCA_Rise_Time	5 usec	Static	Identical for all conformant PHY
aCCA_Fall_Time	1 usec	Static	Identical for all conformant PHY
aRxTx_Turnaround_Time	0 usec	Static	Identical for all conformant PHY
aRx_Propagation_Delay	1.5 usec	Static	Identical for all conformant PHY
aTx_Propagation_Delay	3.5 usec	Static	Identical for all conformant PHY
aPLCP_Time	60 usec 1mbps 40 usec 2mbps	Static	Identical for all conformant PHY
aPHY_SAP_Delay	13.6 usec 1mbps 9.6 usec 2mbps	Static	Identical for all conformant PHY
aCCA_Watchdog_Timer_Max	implementation dependent	Dynamic	A conformant PHY may set this via the LME
aCCA_Watchdog_Count_Max	implementation dependent	Dynamic	A conformant PHY may set this via the LME
aCCA_Watchdog_Timer_Min	22 μs.	Static	Identical for all conformant PHY
aCCA_Watchdog_Count_Min	1	Static	Identical for all conformant PHY
aChannel_Transit_Delay	*100* ~~25~~ nsec	Static	Identical for all conformant PHY
aChannel_Transit_Variance	*100* ~~25~~ nsec	Static	Identical for all conformant PHY
aPSDU_Maximum	2500 octets	Static	Identical for all conformant PHY
aPSDU_Minimum	0 octets	Static	Identical for all conformant PHY
aPSDU_Current_Maximum	*aPSDU_Maximum* ~~implementation dependent~~	*Static* ~~Dynamic~~	*Identical for all conformant PHY* ~~A conformant PHY may set this via the LME~~
aSupported_Tx_Rates	implementation dependent	Static	All conformant PHY must include the value 000 (1 Mbps).

aSupported_Rx_Rates	implementation dependent	Static	All conformant PHY must include the values 000 (1 Mbps) and 001 (2 Mbps).
aBSS_Basic_Rate_Set	000, 001	Static	Identical for all conformant PHY
aStation_Basic_Rate	implementation dependent	Dynamic	A conformant PHY may set this via the LME
aExtended_Rate_Set	implementation dependent	Static	Rates not in the BSS_Basic_Rate_Set which are supported by the PHY
aPLCP_Rate	000, 001	Static	The PLCP rate must be a member of the BSS_Basic_Rate_Set, and if the data rate is also a member of the BSS_Basic_Rate_Set, then the PLCP_Rate is the same.
aPreferred_Tx_Rate	implementation dependent	Dynamic	A conformant PHY may set this via the LME.
aPreferred_Rx_Rate	implementation dependent	Dynamic	A conformant PHY may set this via the LME.

12.5. PHY Parameters

This section does not provide the definition of the MIB objects, but only provides the Infrared PHY - specific values for the MIB Objects whose definitions and ASN.1 are in Section 9 of this Standard.

Parameter	Value	Comments
aCCA_Rise_Time	5 µsec maximum	conformant PHY may implement a faster CCA mechanism, but must present 5 µsec in their MIB for interoperability
aCCA_Fall_Time	1 µsec maximum	conformant PHY may implement a faster CCA mechanism, but must present 1 µsec in their MIB for interoperability
aRx_Propogation_Delay	1.5 µsec maximum	conformant PHY may implement a faster receive processing mechanism, but must present 1.5 µsec in their MIB for interoperability
aTx_Propogation_Delay	3.5 µsec maximum	conformant PHY may implement a faster transmit processing mechanism, but must present 3.5 µsec in their MIB for interoperability