

5 GHz, U-NII Band, L-PPM

Physical Layer Specification

1.1 Introduction

This document describes the physical layer proposed by RadioLAN Inc. for the 5 GHz, U-NII, L-PPM wireless LAN system.

1.1.1 Physical Layer Functions

The L-PPM contains three functional entities: the physical medium dependent function, the physical layer convergence function, and the layer management function.

1.1.1.1 Physical Layer Convergence Procedure Sublayer

In order to allow the MAC to operate with minimum dependence on the PMD sublayer, a physical layer convergence is defined. This layer simplifies the physical interface to the MAC services.

1.1.1.2 Physical Medium Dependent Sublayer

The physical medium dependent sublayer provides a transmission to send or receive data between two or more nodes using 5 GHz U-NII band with 16-PPM modulation.

1.1.1.3 Physical Layer Management Entity

The physical LME performs management of the local physical layer functions in conjunction with the MAC management entity.

1.2 L-PPM Physical Layer Convergence Procedure Sublayer

1.2.1 Physical Layer Convergence Procedure Frame Format

The following figure shows the format of PPDU including the preamble, start frame delimiter, MPDU and CRC.

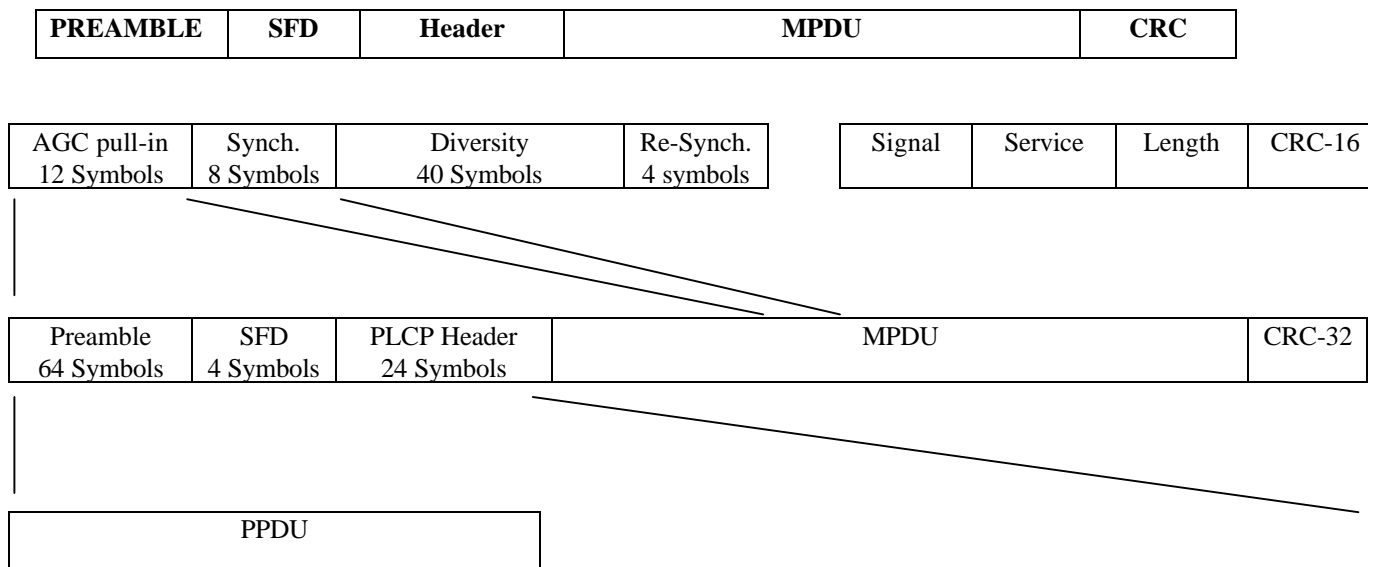


Figure 1. PLCP Frame Format

A preamble consisting of 64 symbols. It is provided so that the receiver can perform AGC, slot synchronization and diversity selection. The Start Frame Delimiter (SFD) indicates the beginning of the MPDU. The Signal field will indicate the data rate, the length field will indicate the MPDU length in bytes, and the CRC-16 is the CCITT CRC-16 for the signal, service and length.

The CRC-32 is a 32-bit CRC-32 with the following formula:

$$\text{CRC-32} = X^{32} + X^{26} + X^{23} + X^{22} + X^{12} + X^{11} + X^{10} + X^8 + X^7 + X^5 + X^4 + X^2 + X + 1$$

1.2.2 PLCP Transmit Procedure

In order to transmit packet, the PHY_TXSTART.request (ANT_SEL) primitive is issued. The PHY will start transmit PLCP preamble using the antenna specified in the primitive. Once the PLCP preamble transmission is completed, data is exchanged between MAC and PHY by a series of PHY_DATA.request primitives issued by the MAC. After the MPDU is sent, MAC issues PHY_TXEND.request to terminate packet transmission. PHY entity will send out 32 bit CRC and return back to receive mode. The LSB is transmitted first.

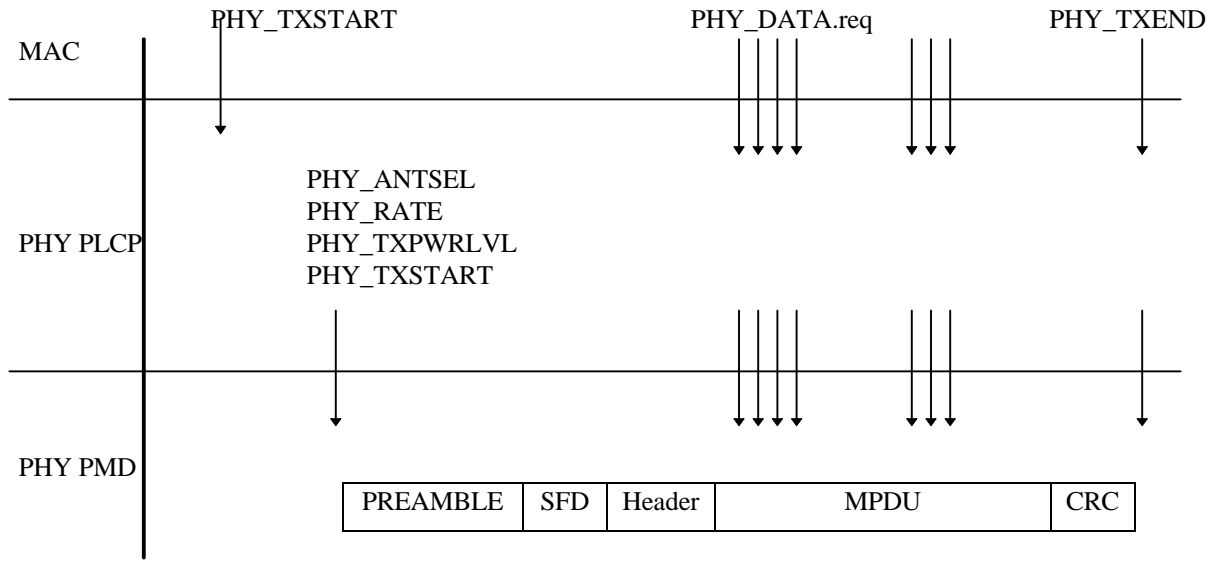


Figure 2. PLCP Transmit Procedure

1.2.3 PLCP Receive Procedure

In order to receive data, PHY_TXSTART.request must be disabled so that the PHY entity is in the receive state. Upon receiving the transmitted energy, the PHY_ED.indicate is issued. The receiver will start waiting for preamble. The PHY should be able to synchronize on the preamble within 12-symbol time. The PHY sends out PHY_CS.indicate to MAC after it receives preamble. If the diversity is enabled and bit error occurs within the RX_DIV_SAMPLE (4 bytes) period, the PHY should switch to the other antenna for packet reception.

If the SFD is received successfully, a PHY_RXSTART.indicate will be issued. The received MPDU bits are assembled into octets and presented to the MAC using a series of PHY_DATA.indicate(DATA) primitive exchanges. After the reception of the final bit of the last MPDU, the PHY issues PHY_RXSTOP.indicate(RX_ERROR). After the PHY_RXSTOP.indicate, the PHY will issue PHY_CCA.Indicate with a state value of IDLE.

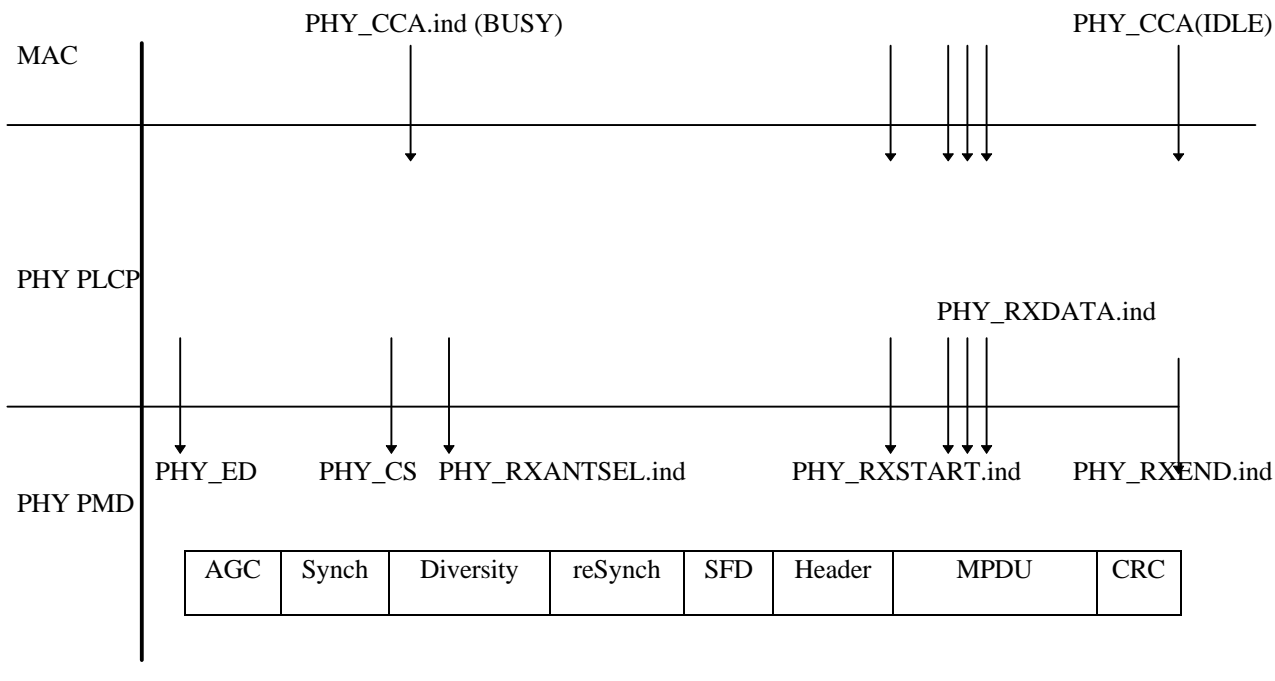


Figure 3. PLCP Receive Procedure

1.3 L-PPM Physical Layer Management Entity (LME)

1.3.1 PLME_SAP Detailed Service Specification

1.3.1.1 PLME_RESET.request

This primitive is a request by LME to reset the PHY.

1.3.1.2 PLEM_CHNL_ID.request

This primitive is a request by LME to set the operational frequency of the PHY.

1.3.1.3 PLME_DIVERSITY.request

This primitive is a request by LME to enable or disable antenna diversity.

1.3.1.4 PLME_RX_DIV_SAMPLE.request

This primitive is a request by LME to set the sample size of the reception diversity.

1.3.1.5 PLME_ANTENNA.request

This primitive is a request by MAC to select the antenna.

1.4 L-PPM Physical Medium Dependent Sublayer

1.4.1 PMD_SAP Detailed Service Specification

1.4.1.1 PHY_DATA.request

This primitive defines the transfer of data from PLCP sublayer to the PMD entity.

1.4.1.2 PHY_DATA.indicate

This primitive defines the transfer of data from PMD entity to the PLCP sublayer.

1.4.1.3 PHY_TXSTART.request

This primitive, generated by the PHY PLCP sublayer, initiates PPDU transmission by the PMD layer. It also provides ANT_SEL as a parameter to indicate the transmission antenna.

1.4.1.4 PHY_TXEND.request

This primitive, generated by the PHY PLCP sublayer, ends PPDU transmission by the PMD layer.

1.4.1.5 PHY_RXSTART.indicate

This primitive, generated by PHY PMD layer, indicate the beginning of the frame reception. It also provides ANT_SEL as a parameter to indicate the antenna used for receiving this packet.

1.4.1.6 PHY_RXSTOP.indicate

This primitive, generated by PHY PMD layer, indicate the end of the frame reception. It also provides RX_ERROR as a parameter to indicate the CRC and symbol errors.

1.4.1.7 PHY_ED.indicate

This primitive, generated by PHY PMD layer, indicates to the PLCP layer that the receiver has detected RF energy in the current channel.

1.4.1.8 PHY_CS.indicate

This primitive, generated by PHY PMD layer, indicates to the PLCP layer that the receiver has detected RF energy and preamble is received.

1.4.2 PMD Operating General Specifications

The following sections provide general specifications for the 16-PPM physical medium dependent sublayer. These specifications apply to both the receive and transmit functions and general operation of a compliant L-PPM PHY.

1.4.2.1 Operating Frequency Range

The L-PPM PHY will operate in the frequency bands of

5.150 to 5.250 GHz

5.250 to 5.350 GHz

5.725 to 5.825 GHz

as allocated by the FCC for the U-NII devices.

1.4.2.2 Channelization

For the three bands, i.e. the lower, middle and the upper bands with 100 MHz available in each band, a total of 9 channels are specified.

Channel_ID	Frequency Band
1	5163.17 – 5189.77 MHz
2	5186.70 – 5213.30 MHz
3	5210.22 – 5236.82 MHz
4	5263.17 – 5289.77 MHz
5	5286.70 – 5313.30 MHz
6	5310.22 – 5336.82 MHz
7	5738.17 – 5764.77 MHz
8	5761.70 – 5788.3 MHz
9	5785.22 – 5811.82 MHz

For the lower and middle band combined, i.e. 200 MHz of bandwidth combined, and the 100 MHz upper band, a total of 10 channels are specified.

Channel_ID	Frequency Band
1	5164.60 – 5191.30 MHz
2	5188.00 – 5214.08 MHz
3	5211.60 – 5238.30 MHz
4	5235.10 – 5261.90 MHz
5	5258.05 – 5285.46 MHz
6	5282.19 – 5308.99 MHz
7	5305.60 – 5332.40 MHz
8	5738.17 – 5764.77 MHz
9	5761.70 – 5788.30 MHz
10	5785.22 – 5811.82 MHz

1.4.2.3 Modulation

The modulation is 16-PPM.

1.4.2.4 Encoding

The encoding for the 16-PPM is 4 bits per symbol, and it is based on a differential and overlapping set of pulse positions.

Data	Pulse Position
0000	100
0001	113.3333
0010	126.6667
0011	140
0100	153.3333
0101	166.6667
0110	180
0111	193.3333

1000	206.6667
1001	220
1010	233.3333
1011	246.6667
1100	260
1101	273.3333
1110	286.6667
1111	300

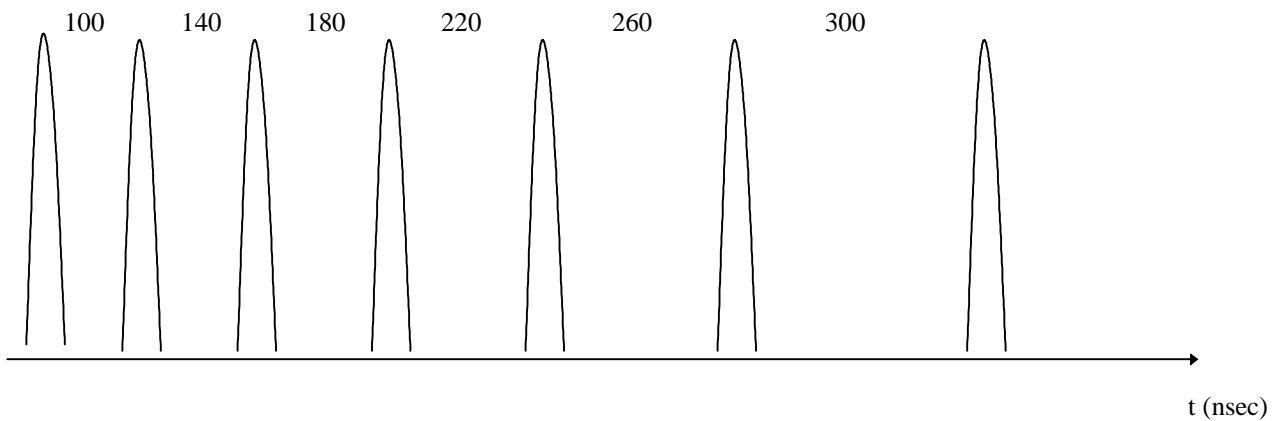


Figure 4. Illustration of an example of 3 bytes of data (000000110110100110111111) encoded by 16-PPM..

1.4.2.5 Interleaving

Cuurently under investigation and simulation.

1.4.2.6 Scrambling and Descrambling

Cuurently under investigation and simulation.

1.4.2.7 Forward Error Correction

Cuurently under investigation and simulation.

1.4.2.8 Channel Data Rate

Based on a uniform distribution of the data, the average symbol rate is 5 Mega Symbols per second, corresponding to 20 Mbit /s as the primary rate, and 10 Mbps as the fall-back rate.

1.4.2.9 Transmit and Receive In-Band and Out-of-band Spurious Emissions

The L-PPM PHY shall conform to in-band and out-of-band spurious emissions as set by FCC for the U-NII devices as specified in the regulation 15.407, and 15.209.

1.4.2.10 Transmit-to-Receive Turn-Around Time

The transmit-to-receive turn-around time shall be less than 4 μsec, measured from the time TXE is de-asserted to the time when the receiver meets full specifications.

1.4.2.11 Receive-to-Transmit Turn-Around Time

The receive-to-transmit turn-around time shall be less than 1 μ sec, measured from the time TXE is asserted to the time when the transmitter meets full specifications.

1.4.2.12 Receive and Transmit Antenna Port Impedance

The transmit and receive antenna port(s) impedance shall be 50 Ohm if the port is exposed.

1.4.2.13 Receive and Transmit VSWR

L-PPM PHY devices shall withstand no damage and remain stable over the range of VSWR between 0 and ∞ .

1.4.2.14 Receive and Transmit Operating Temperature Range

L-PPM devices for U-NII applications (indoor) shall operate between 0 and 50 degrees.

1.4.2.15 Transmit power levels

The maximum output power for the L-PPM, U-NII devices are 50, 250 and 1000 mW for the lower, middle and upper bands respectively. The maximum EIRP for the L-PPM, U-NII devices are 200, 1000, and 4000 mW for lower, middle and upper bands respectively.

1.4.2.16 Basic Pulse-Shape and Parameters

The basic pulse-width measured at its offset bias-crossings will be 36 ± 2 nsec. The pulse shape will be raised-cosine with a $\beta = 0.5$.

1.4.2.17 Receiver Minimum Input Level Sensitivity

The BER shall be less than 10^{-5} for an input level of -68 dBm measured at the antenna connector. This BER is for the 20 Mbps, 16-PPM modulated signal.

1.4.2.18 Receiver Maximum Input Level

The BER shall be less than 10^{-5} for an input level of -15 dBm measured at the antenna connector. This BER is for the 20 Mbps, 16-PPM modulated signal.

1.4.2.19 Receiver adjacent Channel Rejection

The adjacent channel rejection shall be equal to or better than goal of 30 dB (currently under investigation) with a BER of 10^{-5} for a 20 Mbps, 16-PPM modulated signal.

1.4.2.20 Clear Channel Assessment

The PHY should be able to perform Clear Channel Assessment (CCA) according to the physical energy and carrier sense. These two status are given by the PMD primitive, PHY_ED.indicate and PHY_CS.indicate, respectively. The CCA should indicate IDLE if there is no energy detect or carrier sense. If the PHY receives 4 symbol errors within 1 μ sec when CCA is BUSY, the carrier is lost and the CCA changes to IDLE.

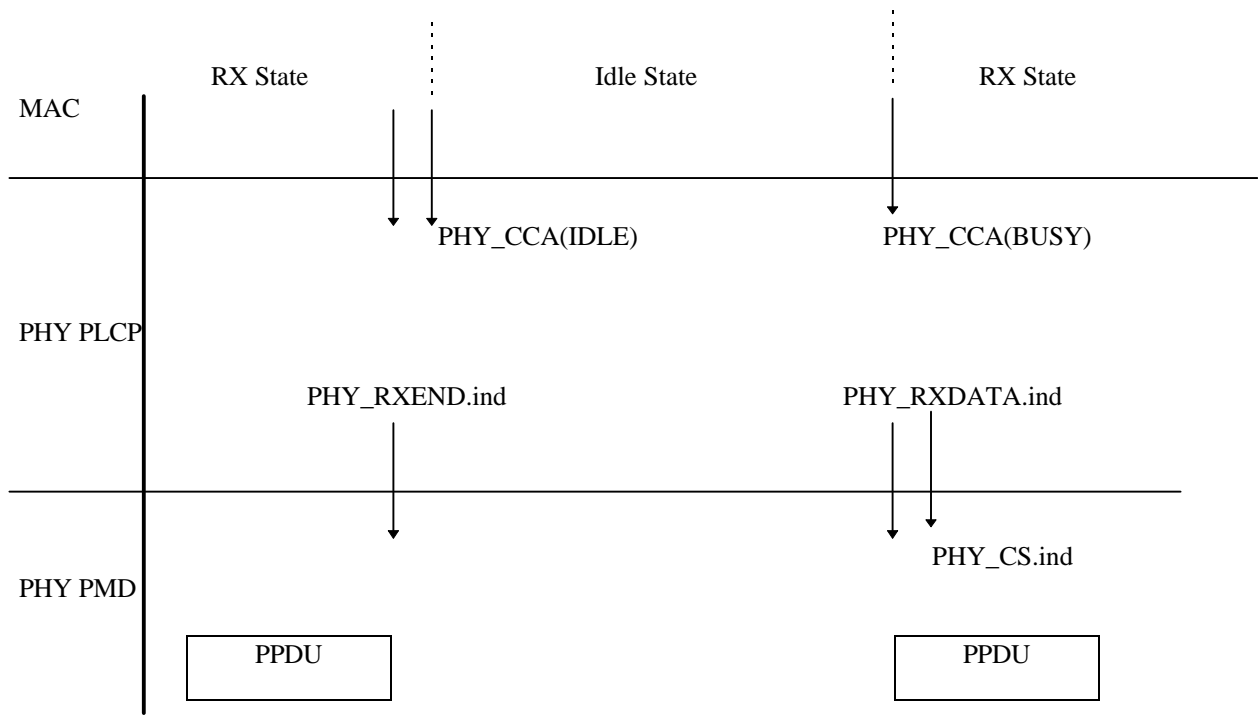


Figure 5. Clear Channel Assessment

1.4.2.21 Back-off Algorithm

The back-off window doubles for every 4 deferrals. The initial back-off window is 32.

1.4.3 Overhead related parameters

1.4.3.1 Slot time

The slot time includes the RX to TX turnaround time (~1 microseconds), energy detection time (~25ns), and propagation delay (~300ns). The slot time is 3 microseconds.

1.4.3.2 Short Inter Frame Space Time

The SIFS time is slightly larger than the transmit-to-receive turn-around time (4 microseconds), and is defined as 5 microseconds.

1.4.3.3 Preamble

The preamble is used for AGC settling-time, synchronization, diversity sampling, and antenna switching. The PHY has to be able to synchronize on the preamble within 12 symbols time. Once the preamble byte is found, PHY_CS.indicate is issued to PLCP. The diversity sampling starts after the preamble byte is received. If any symbol error occurs during the diversity sampling time, PHY will switch to the other antenna. The PHY must see another preamble byte in order to get synchronized to the data stream.

Appendix A.

Bit Error Rate in AWGN channel, Multipath fading channel, and multipath fading channel with diversity ($D=2$).

Figure A.1. BER vs. E_b/N_0 performance of L-PPM with and without diversity and multipath.