12. 2.4 GHz ISM Band Direct Sequence Spread Spectrum Physical Layer Specification

12.1. Introduction

This section describes the physical layer for the Direct Sequence Spread Spectrum (DSSS) system. The Radio Frequency LAN system is initially aimed for the 2.4 GHz ISM band as provided in the USA according to Document FCC 15.247 and in Europe by ETS 300-328. Other countries have similar regulations.

The DSSS system provides a 1 Mb/s and/or a 2 Mb/s wireless LAN. According to the FCC regulations, the DSSS system must provide a processing gain of at least 10 dB. This is accomplished by chipping the baseband signal at 11 MHz with an 112-chip Barker sequence. The DSSS system uses baseband modulations of Differential Binary Phase Shift Keying (DBPSK) and Differential Quadrature Phase Shift Keying (DQPSK) to provide the 1 and 2 Mb/s data rates, respectively.

Key characteristics resulting from spreading of DSSS systems are the low radiated power per spectral band, robustness against interference, processing gain, and insensitivity to multipath effects of the channel.

12.1.1. Scope

This section describes the physical layer services provided to the 802.11 wireless LAN MAC by the 2.4 GHz Direct Sequence Spread Spectrum system. The DSSS PHY layer consists of two protocol functions:

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 using the associated physical medium dependent system.

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

Each physical medium dependent sublayer for the DSSS 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 might be null.

12.1.2. DSSS Physical Layer Functions

The 2.4 GHz DSSS PHY architecture is shown in Figure 12-1. The DSSS 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 DSSS Physical Layer service is provided to the Media Access Control through the physical layer service primitives described in Section 98.
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.
12.1.2.2. Physical Medium Dependent Sublayer

The physical medium dependent sublayer provides a means to send or receive data between two or more stations. This section is concerned with the 2.4 GHz ISM bands using Direct Sequence modulation.

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. Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPDU</td>
<td>PHY Protocol Data Unit</td>
</tr>
<tr>
<td>CCA</td>
<td>Clear Channel Assessment</td>
</tr>
<tr>
<td>CRC</td>
<td>Cyclic Redundancy Check</td>
</tr>
<tr>
<td>DBPSK</td>
<td>Differential Binary Phase Shift Key</td>
</tr>
<tr>
<td>DQPSK</td>
<td>Differential Quadrature Phase Shift Key</td>
</tr>
<tr>
<td>DSSS</td>
<td>Direct Sequence Spread Spectrum</td>
</tr>
<tr>
<td>ED</td>
<td>Energy Detection</td>
</tr>
<tr>
<td>FCS</td>
<td>Frame Check Sequence</td>
</tr>
<tr>
<td>FER</td>
<td>Frame Error Rate</td>
</tr>
<tr>
<td>LME</td>
<td>Layer Management Entity</td>
</tr>
<tr>
<td>LSB</td>
<td>Least Significant Bit</td>
</tr>
<tr>
<td>MAC</td>
<td>Media Access Control</td>
</tr>
<tr>
<td>MIB</td>
<td>Management Information Base</td>
</tr>
<tr>
<td>MPDU</td>
<td>MAC Protocol Data Unit</td>
</tr>
<tr>
<td>MSB</td>
<td>Most Significant Bit</td>
</tr>
<tr>
<td>PLCP</td>
<td>Physical Layer Convergence Procedure</td>
</tr>
<tr>
<td>PLME</td>
<td>PHY Layer Management Entity</td>
</tr>
<tr>
<td>PMD</td>
<td>Physical Medium Dependent</td>
</tr>
<tr>
<td>PMD_SAP</td>
<td>Physical Medium Dependent Service Access Point</td>
</tr>
<tr>
<td>PN</td>
<td>Pseudo Noise (PN code sequence)</td>
</tr>
<tr>
<td>PPDU</td>
<td>PHY Protocol Data Unit</td>
</tr>
<tr>
<td>RSSI</td>
<td>Received Signal Strength Indication</td>
</tr>
<tr>
<td>SAP</td>
<td>Service Access Point</td>
</tr>
<tr>
<td>SFD</td>
<td>Start Frame Delimiter</td>
</tr>
<tr>
<td>SQ</td>
<td>Signal Quality (PN code correlation strength)</td>
</tr>
<tr>
<td>SAP</td>
<td>Service Access Point</td>
</tr>
<tr>
<td>TXE</td>
<td>Transmit Enable</td>
</tr>
</tbody>
</table>

12.1.4. Service Specification Method and Notation

The models represented by figures and state diagrams are intended to be 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 DS PHY compliant developer.

The service of a 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.
12.2. DSSS Physical Layer Convergence Procedure Sublayer

12.2.1. Introduction

This section provides a convergence procedure in which MPDUs are converted to and from PPDUs. During transmission, the MPDU is prepended with a PLCP preamble and header to create the PPDU. At the receiver, the PLCP preamble and header are processed to aid in demodulation and delivery of the MPDU.

12.2.2. Physical Layer Convergence Procedure Frame Format

Figure 12-2 shows the format for the PPDU including the PLCP preamble, the PLCP header and the MPDU. The PLCP preamble contains the following fields: synchronization (SYNC) and Start Frame Delimiter (SFD). The PLCP header contains the following fields: 802.11 signaling (SIGNAL), 802.11 service (SERVICE), length (LENGTH), CCITT CRC-16. Each of these fields shall be described in detail in section 12.2.3.

12.2.3. PLCP Field Definitions

The entire PLCP preamble and header shall be transmitted using the 1 Mb/s BPSK modulation described in section 12.4.7. All transmitted bits shall be scrambled using the feedthrough scrambler described in section 12.4.

12.2.3.1. PLCP Synchronization (SYNC)

The synchronization field shall consist of 128 bits of scrambled 1 bits. This field is provided so that the receiver can perform the necessary operations for synchronization.

12.2.3.2. PLCP Start Frame Delimiter (SFD)

The Start Frame Delimiter is provided to indicate the start of PHY dependent parameters within the PLCP preamble. The Unique Word consist of a 16 bit field, hF3A0 (MSB to LSB). The LSB shall be transmitted first in time.

12.2.3.3. PLCP 802.11 Signal Field (SIGNAL)

The 8 bit 802.11 signal field indicates to the PHY the modulation which will be used for transmission (and reception) of the MPDU. The data rate is equal to the Signal Field value multiplied by 100Kb/s. The DSSS PHY currently supports two mandatory modulation services given by the following 8 bit words, where the LSB is transmitted first in time:

Submission       Page 491332      DS-PHY (Mike Trompower, Aironet)
a) h0A (MSB to LSB) for 1 Mb/s BPS DBPSK
b) h14 (MSB to LSB) for 2 Mb/s BPS DQPSK

The DSSS PHY rate change capability is described in section 12.2.5. This field is protected by the CCITT CRC-16 frame check sequence described in section 12.2.3.6.

12.2.3.4. PLCP 802.11 Service Field (SERVICE)

The 8 bit 802.11 service field is reserved for future use. The value of h00 signifies 802.11 device compliance. This field must be set to h00. The LSB shall be transmitted first in time. This field is protected by the CCITT CRC-16 frame check sequence described in section 12.2.3.6.

12.2.3.5. PLCP Length Field (LENGTH)

The PLCP length field is an unsigned 16 bit integer which indicates the number of octets (4 to \(2^{16}\) as defined by aMPDU_maximum [per 109.1.4.23]) to be transmitted in the MPDU. The transmitted value is provided by the LENGTH parameter in the PHY_DATA.request primitive described in section 98. The LSB (least significant bit) shall transmitted first in time. This field is protected by the CCITT CRC-16 frame check sequence described in section 12.2.3.6.

12.2.3.6. PLCP CRC Field (CCITT CRC-16)

The 802.11 signal, 802.11 service, and length fields shall be protected with a CCITT CRC-16 FCS (frame check sequence). The CCITT CRC-16 FCS is the ones complement of the remainder generated by the modulo 2 division of the protected PLCP fields by the polynomial:

\[ x^{16} + x^{12} + x^{5} + 1 \]

The protected bits will be processed in transmit order. All FCS calculations shall be made prior to data scrambling.

As an example, the signal, PLCP service, and length fields for a DBPSK signal with a packet length of 192 would be given by the following:

0101 0000 0000 0000 0000 0011 0000 0000 (left most bit transmitted first in time)

The ones complement FCS for these protected PLCP preamble bits would be the following:

0101 1011 0101 0111 (left most bit transmitted first in time)

Figure 12-3 depicts this example.
Transmit and Receive PLCP Header CRC16 Calculator

CRC16 Polynomial: \( G(x) = X^{16} + X^{12} + X^5 + 1 \)

Preset to "1's"

Sequence:
1) PRESET TO ALL
2) SHIFT SIGNAL, SERVICE, LENGTH THROUGH SR
3) Take 1's COMPLEMENT OF REMAINDER Q's
4) Transmit Out SERIAL (MSB)

XOR

SERIAL DATA INPUT

CRC16

SERIAL Data (Parity) Output

16 Bit SREG

MSB

LSB

Complement

(Parity) 0 (MSB First)
An illustrative programming example using the above of the CCITT CRC-16 FCS follows:

```c
#include <stdio.h>

int data[32] = {0,1,0,1, 0,0,0,0 , 0,0,0,0, 0,0,0,0, 0,0,0,0 , 0,0,0,1, 0,0,0,0, 0,0,0,0};

main() {
    int residue, fdbk;
    residue = 0xFFFF;
    printf("%d ", residue);
    print((stdout, residue, 16));
    printf("binary-print-function

    for (i = 0; i < 32; i++) {
        fdbk = (residue >> 16) ^ data[i];
        residue = (2 * residue) & 0xFFFF;
        if (fdbk) residue ^= 0x1021;
        printf("%d ", data[i]);
        printf((stdout, residue, 16));
    }
}"
```

Figure 12-3: CCITT CRC-16 implementation
12.2.4. PLCP / DS PHY Data Scrambler and Descrambler

The polynomial $1 + z^{-4} + z^{-7} + z^{-4} + 1$ shall be used to scramble ALL bits transmitted by the DSSS PHY. The feedthrough configuration of the scrambler is self initializing. No prior initialization of the scrambler is required for either transmit or receive processing. Figures 12-3 and 12-4 show typical implementations of the data scrambler and descrambler. Other implementations are possible.

The scrambler should be initialized to any state except all ones when transmitting.
Scrambler Polynomial: \( G(z) = z^{-7} + z^{-4} + 1 \)

Figure 12-3: Data Scrambler
12.2.5. PLCP Data Modulation and Modulation Rate Change

The PLCP preamble shall be transmitted using the 1 Mb/s DBPSK modulation. The 802.11 signal field will indicate the modulation which will be used to transmit the MPDU. The transmitter and receiver will initiate the modulation indicated by the 802.11 signal field starting with the first symbol (1 bit for DBPSK, 2 bits for DQPSK) of the MPDU. The MPDU transmission rate is set by the RATE parameter in PHY_DATA.request primitive.

12.2.6. PLCP Transmit Procedure

The PLCP transmit procedure is shown in Figure 12-5. 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 PHY_DATA.confirm primitives are not shown in Figure 12-5.

Based on the status of CCA indicated by PHY_DATA.indicate, the MAC will assess that the channel is clear. A clear channel is indicated by PHY_DATA.indicate(END-OF-ACTIVITY). If the channel is clear, transmission of the MPDU is initiated by issuing the PHY_DATA.request (START-OF-ACTIVITY) primitive. The TXVECTOR elements for the PHY_DATA.request (START-OF-ACTIVITY) are the PLCP header parameters SIGNAL, SERVICE and LENGTH and the PMD parameters of ANT_STATE, CHNL_ID, and TXPWR_LEVEL, LENGTH, ANSSEL, RATE (SIGNALING), SERVICE, CHNL_ID, and TXPWR_LEVEL.
The PLCP will issue PMD_ANTSEL, PMD_RATE, PMD_SERVICE, PMD_CHANNEL, CHNL_ID, and PMD_TXPWR_LVL primitives to configure the PHY. The PLCP will then issue a PMD_TXE enable and the PHY entity will immediately initiate data scrambling and transmission of the PLCP preamble based on the parameters passed in the PHY_DATA.request primitive. The time required for TX power on ramp described in section 12.4.7 is included in the PLCP synchronization field. Once the PLCP preamble transmission is completed, data is exchanged between the MAC and the PHY by a series of PHY_DATA.request(DATA, octet) issued by the MAC and PHY_DATA.confirm primitives. The modulation rate change, if any, is initiated with the first data symbol of the MPDU as described in section 12.2.5. The PHY proceeds with MPDU transmission through a series of data octet transfers from the MAC. At the PMD layer, the data octets are sent in LSB to MSB order and presented to the PHY layer through PMD_DATA.request primitives. Transmission is terminated by the MAC through the primitive PHY_DATA.request(END-OF-DATA) followed by PHY_DATA.request(END-OF-ACTIVITY). PMD_TXE is disabled with the end of activity. The termination occurs after the transmission of the final bit of the last MPDU octet. The number of octets transmitted must equal the number supplied in the DSSS PHY preamble LENGTH. The packet transmission is completed and the PHY entity enters the default receive state (i.e., PMD_TXE is disabled). It is recommended that chipping continues during power down.
12.2.6.1. Transmit State Machine

A typical state machine implementation of the PLCP transmit procedure is provided in Figure 12-6.
PHY_DATA.request(start-of-activity, length, rate, service, chnId, txPwr_level)

- Initialize
  - PMD_TX_PWR_LVL.req
  - PMD_CHANNEL.req

- TX SYNC PATTERN
  - PMD_RATE.req (BPSK)
  - PMD_TXE.req (TX)
  - TX 128 scrambled 1's via PMD_DATA.req

- TX PLCP DATA
  - TX 16 bit sync
  - TX 8 bit SIGNAL
  - TX 8 bit SERVICE
  - TX 16 bit LENGTH
  - TX 16 bit CRC via PMD_DATA.req

- SETUP MPDU TX
  - if RATE = QPSK
    - PMD_RATE.req (QPSK)
    - PHY_DATA.confirm
      - set Length count

TX MPDU OCTET

- PHY_DATA.REQ(DATA)
  - get octet form MAC
  - Set Octet bit count

TX SYMBOL

- PMD_DATA.req

- Decrement Bit
  - decrement bit count by bits per symbol
    - bit count = 0
    - bit count <> 0

- Decrement Length
  - decrement length count
    - length <> 0
      - PHY_DATA.confirm
    - length = 0

Switch to RX STATE

- PMD_TXE.req(RX)
**12.2.7. PLCP Receive Procedure**

The PLCP receive procedure is shown in Figure 12-7. All commands issued by 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 PHY_DATA.confirm primitives are not shown in Figure 12-7.

In order to receive data, PMD_TXE must be disabled so that the PHY entity is in the default receive state. Further, the PHY must be set to operate at the appropriate CHNL_ID through Station Management via the Layer Management Service Access Point (LMSAP). Other receive parameters such as RSSI, SQ (signal quality), and indicated RATE may also be accessed via the LMSAP.

Upon receiving the transmitted energy, the PMD_ED will be enabled (according to section 12.4.8.4) as the RSSI strength reaches the ED_THRESHOLD. If the transmitted energy is associated with a DSSS PHY PLCP and if the PHY entity acquires PN code lock based on the SQ_THRESHOLD, then PMD_CS will be enabled. Based on the CCA (see section 12.4.8.4) these conditions can be used to indicate activity to the
MAC. PHY-DATA.indicate(START_OF_ACTIVITY) is issued for energy detection or code lock prior to correct reception of the PLCP frame. The PMD primitives PMD_SQ and PMD_RSSI are issued to update the RSSI and SQ parameters reported to the MAC.

The PHY entity begins searching for the Unique Word field. Once the Unique word field is detected, CCITT CRC-16 processing is initiated and the PLCP 802.11 signal, 802.11 service, and Length fields are received. The CCITT CRC-16 FCS will be processed. If the CCITT CRC-16 FCS check fails, a PHY_DATA.indicate(END-OF-DATA) primitive will be issued and PHY receiver will be reset. Should code lock be lost during reception prior to completion of either the PLCP header or the full MPDU as indicated by the length field, the PLCP will issue a PHY-DATA.indicate(END-OF-DATA, carrier_lost).

If the PLCP preamble reception is successful a PHY_DATA.indicate(START_OF_DATA) will be issued. The RXVECTOR associated with this primitive includes the signaling field, the service field, the length field, PMD_RSSI, and PMD_SQ.

The received MPDU bits are assembled into octets and presented to the MAC using a series of PHY_DATA.indicate(DATA, octet) and PHY_DATA.confirm primitive exchanges. The rate change indicated in the 802.11 signal field is initiated with the first symbol of the MPDU as described in section 12.2.5. The PHY proceeds with MPDU reception. Reception is terminated after the reception of the final bit of the last MPDU octet indicated by the PLCP preamble LENGTH field. Depending on the state of energy detection and code lock, either a PHY_DATA.indicate(END-OF-DATA, no_error) or a PHY_DATA.indicate(END-OF-ACTIVITY) primitive is issued to the MAC. Should code lock/synchronization be lost prior to the end of the MPDU as indicated in the PLCP LENGTH field, the error condition PHY_DATA.indicate(END-OF-DATA, carrier_lost) will be reported to the MAC.
12.2.7.1. Receive State Machine

A typical state machine implementation of the PLCP transmit procedure is provided in Figure 12-8.
PHY_DATA.ind (End-of-Activity)

RX Idle State
Wait for
PMD_ED.ind or
PMD_CS.ind

PMD_DATA.ind

PHY_DATA.ind (Start-of-Activity)

Detect SYNC PATTERN
Wait until SFD is detected

PMD_CS.ind

PHY DATA.ind

RX PLCP Fields
RX 8 bit SIGNAL
RX 8 bit SERVICE
RX 16 bit LENGTH

PMD_CS.ind

(disabled)
or
PLCP Field Out Of Spec.

PMD_CS.ind

(disabled)
or
CRC FAIL

PHY_DATA.ind (End-of-Activity)
or
(End-of-Data)

RX PLCP CRC
RX and Test CRC

SETUP MPDU RX
if RATE = QPSK
PMD_RATE.req (QPSK)
set Length count
set Octet bit count

PMD_CS.ind (disabled)

PHY_DATA.ind

RX SYMBOL

PMD_DATA.ind

Decrement Bit
decrement bit count
by bits per symbol

bit count <> 0

Decrement Length
decrement length count
set Octet bit count

length = 0

PHY_DATA.ind (DATA)

END OF MPDU RX
if PMD_ED and PMD_CS
disabled
PHY_DATA.ind (END-OF-DATA/ACTIVITY)
ELSE
PHY_DATA.ind (END-OF-DATA)
12.3. DSSS Physical Layer Management Entity (PLME)

12.3.1. PLMEMPW_SAP Sublayer Management primitives

The following message may be sent between the PHY sublayer entities and intra layer of higher Layer Management Entities (LME).

<table>
<thead>
<tr>
<th>Primitive</th>
<th>Request</th>
<th>Indicate</th>
<th>Confirm</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLMEMPW_RESET</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

Table 12-1: PLMEMPW_SAP Sublayer Management Primitives

12.3.2. PLMEMPW_SAP Management Service Primitive Parameters

There are currently no parameters associated with the PLMEMPW_SAP service primitives.
12.3.3. **PLMEMPHY_SAP Detailed Service Specification**

12.3.3.1. **PLMEMPHY_RESET.request**

**Function**

This primitive is a request by the LME to reset the PHY. The PHY is always reset to the receive state to avoid accidental data transmission.

**Semantics of the Service Primitive**

The primitive shall provide the following parameters:

- **PLMEMPHY_RESET.request**

  There are no parameters associated with this primitive.

**When Generated**

This primitive is generated at any time to reset the PHY.

**Effect of Receipt**

Receipt of this primitive by the PHY sublayer will cause the PHY entity to reset both the transmit and the receive state machines and place the PHY into the default-receive state.

12.3.3.2. **PLMEMPHY_RESET.confirm**

**Function**

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

**Semantics of the Service Primitive**

The primitive shall provide the following parameters:

- **PLMEMPHY_RESET.confirm**

  There are no parameters associated with this primitive.

**When Generated**

This primitive is generated as a response to the **PLMEMPHY_RESET.request** once the PHY has successfully completed the reset.

**Effect of Receipt**

The effect of the receipt of this primitive by the LME is unspecified.

12.3.4. **DSSS Physical Layer Management Information Base**

The following parameters will be included in the DS-PHY MIB. All fields are 8 bits in length and represent either integers from 0 to 255 or as the exact field definition in the PLCP or PMD sections of this document.
All DSSS Physical Layer Management Information Base variables are defined in Section 10 with specific values defined in Appendix A.

<table>
<thead>
<tr>
<th>Managed-Object</th>
<th>Default-Value/Range</th>
<th>Operational Semantics</th>
<th>Operational Behaviour/Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHY_Type</td>
<td>DSSS-2.4-(02)</td>
<td>Static</td>
<td>Identical for all DSSS PHYs operating in 2.4 GHz.</td>
</tr>
<tr>
<td>Num_Supported_Regulatory_Domains</td>
<td>implementation-dependent</td>
<td>Static</td>
<td>Reports the number of approvals received</td>
</tr>
<tr>
<td>FCC</td>
<td>10 / (10-1F)</td>
<td>Static</td>
<td>as-appropriate</td>
</tr>
<tr>
<td>DOC</td>
<td>20 / (20-2F)</td>
<td>Static</td>
<td>as-appropriate</td>
</tr>
<tr>
<td>ETSI</td>
<td>30 / (30-3F)</td>
<td>Static</td>
<td>as-appropriate</td>
</tr>
<tr>
<td>MKK</td>
<td>40 / (40-4F)</td>
<td>Static</td>
<td>as-appropriate</td>
</tr>
<tr>
<td>Slot_Time</td>
<td>20-usec</td>
<td>Static</td>
<td></td>
</tr>
<tr>
<td>CCA_Assessment_Time</td>
<td>15-usec</td>
<td>Static</td>
<td>Energy-detect-time</td>
</tr>
<tr>
<td>RxTx_Turnaround</td>
<td>5-usec</td>
<td>Static</td>
<td></td>
</tr>
<tr>
<td>TxRx_Turnaround</td>
<td>10-usec</td>
<td>Static</td>
<td></td>
</tr>
<tr>
<td>SIFS_Time</td>
<td>10-usec</td>
<td>Static</td>
<td></td>
</tr>
<tr>
<td>Num_RX_Antenna</td>
<td>implementation-dependent</td>
<td>Static</td>
<td>reports number of physical antenna connectors and/or</td>
</tr>
<tr>
<td>Num_TX_Antenna</td>
<td>implementation-dependent</td>
<td>Static</td>
<td>fixed integrated RX and TX antennas</td>
</tr>
<tr>
<td>Antenna_Diversity_Control</td>
<td>0x00 = on, 0xYY = dedicated-antenna #YY</td>
<td>Dynamic</td>
<td>Diversity-on will use all antennas. Diversity is off otherwise and will only use the selected antenna YY</td>
</tr>
<tr>
<td>Num_TX_PowerLevels</td>
<td>implementation-dependent</td>
<td>Static</td>
<td>reports number of supported power levels.</td>
</tr>
<tr>
<td>PowerLevel_1</td>
<td>value in dBm (0-30)</td>
<td>Static</td>
<td>MAC must determine the</td>
</tr>
<tr>
<td>PowerLevel_2</td>
<td>value in dBm (0-30)</td>
<td>Static</td>
<td>allowed levels for a part-</td>
</tr>
<tr>
<td>PowerLevel_xXx</td>
<td>value in dBm (0-30)</td>
<td>Static</td>
<td></td>
</tr>
<tr>
<td>Max_TXPower_Level</td>
<td>value in dBm (0-30)</td>
<td>Dynamic</td>
<td></td>
</tr>
<tr>
<td>Sleep_TurnOn_Time</td>
<td>value in usec</td>
<td>implementation-dependent</td>
<td></td>
</tr>
<tr>
<td>Doze_TurnOn_Time</td>
<td>value in usec</td>
<td>implementation-dependent</td>
<td></td>
</tr>
</tbody>
</table>

12.4. DSSS Physical Medium Dependent Sublayer

12.4.1. Scope and Field of Application

This section describes the PMD services provided to the PLCP for the DSSS Physical Layer. Also defined in this section are the functional, electrical, and RF characteristics required for interoperability of implementations conforming to this specification. The relationship of this specification to the entire DSSS PHY Layer is shown in Figure 12-9.
12.4.2. Overview of Service

The DSSS Physical Medium Dependent Sublayer accepts Physical Layer Convergence Procedure sublayer service primitives and provides the actual means by which data is transmitted or received from the media. The combined function of DSSS PMD sublayer primitives and parameters for the receive function results in a data stream, timing information, and associated received signal parameters being delivered to the PLCP sublayer. A similar-like functionality is provided for data transmission.
12.4.3. Overview of Interactions

The primitives associated with the 802.11 PLCP sublayer to the DSSS PMD falls into two basic categories:

a) Service primitives that support PLCP peer-to-peer interactions.
b) Service primitives that have local significance and support sublayer-to-sublayer interactions.

12.4.4. Basic Service and Options

All of the service primitives described in this section are considered mandatory unless otherwise specified.

12.4.4.1. PMD_SAP Peer-to-Peer Service Primitives

The following table indicates the primitives for peer-to-peer interactions.

<table>
<thead>
<tr>
<th>Primitive</th>
<th>Request</th>
<th>Indicate</th>
<th>Confirm</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>PMD_DATA</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 12-2: PMD_SAP Peer-to-Peer Service Primitives

12.4.4.2. PMD_SAP Sublayer-to-Sublayer Service Primitives

<table>
<thead>
<tr>
<th>Primitive</th>
<th>Request</th>
<th>Indicate</th>
<th>Confirm</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>PMD_TXE</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PMD_ANTSEL</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PMD_DIVERSITY</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PMD_TXPWRLVL</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PMD_CHANNELFREQ</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PMD_RATE</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PMD_RSSI</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PMD_SQ</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PMD_CS</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PMD_ED</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 12-3: PMD_SAP Sublayer-to-Sublayer Service Primitives

12.4.4.3. PMD_SAP Service Primitive Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Associate Primitive</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TXD_UNIT</td>
<td>PMD_DATA.request</td>
<td>One(1), Zero(0): DBPSK di bit combinations 00,01,11,10: DQPSK</td>
</tr>
<tr>
<td>RXD_UNIT</td>
<td>PMD_DATA.indicate</td>
<td>One(1), Zero(0): DBPSK di bit combinations 00,01,11,10: DQPSK</td>
</tr>
<tr>
<td>RF_STATE</td>
<td>PMD_TXE.request</td>
<td>Receive, Transmit</td>
</tr>
<tr>
<td>ANT_STATE</td>
<td>PMD_ANTSEL.indicate</td>
<td>1 to 256</td>
</tr>
<tr>
<td></td>
<td>PMD_ANTSEL.request</td>
<td></td>
</tr>
<tr>
<td>DIV_CONTROL</td>
<td>PMD_DIVERSITY.request</td>
<td>On, Off</td>
</tr>
<tr>
<td>TXPWRLVL</td>
<td>PMD_TXPWRLVL</td>
<td>0,1,2,3 (max of 4 levels)</td>
</tr>
<tr>
<td>CHNL_ID</td>
<td>PMD_CHANNELFREQ.request</td>
<td>1 to 124</td>
</tr>
<tr>
<td>RATE</td>
<td>PMD_RATE.indicate</td>
<td>h0A for 1 Mb/s BPS DBPSK</td>
</tr>
<tr>
<td></td>
<td>PMD_RATE.request</td>
<td>h14 for 2 Mb/s BPS DQPSK</td>
</tr>
<tr>
<td>RSSI</td>
<td>PMD_RSSI.indicate</td>
<td>0-7 bits of RSSI</td>
</tr>
</tbody>
</table>
12.4.5. PMD_SAP Detailed Service Specification

The following section describes the services provided by each PMD primitive.

12.4.5.1. PMD_DATA.request

Function

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

Semantic of the Service Primitive

The primitive shall provide the following parameters:

\[ \text{PMD\_DATA}\text{-request}(\text{TXD\_UNIT}) \]

The TXD_UNIT parameter takes on the value of either ONE(1) or ZERO(0) for DBPSK modulation or the di-bit combination 00, 01, 11, or 10 for DQPSK modulation. This parameter represents a single block of data which in turn is used by the PHY to be differential encoded into a DBPSK or DQPSK transmitted symbol. The symbol itself is spread by the PN code prior to transmission.

When Generated

This primitive is generated by the PLCP sublayer to request transmission of a symbol. The data clock for this primitive is supplied by PMD layer based on the PN code repetition.

Effect of Receipt

The PMD performs the differential coding, PN code modulation, and transmission of the data.

12.4.5.2. PMD_DATA.indicate

Function

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

Semantic of the Service Primitive

The primitive shall provide the following parameters:

\[ \text{PMD\_DATA}\text{-indicate}(\text{RXD\_UNIT}) \]

The RXD_UNIT parameter takes on the value of ONE(1) or ZERO(0) for DBPSK modulation or as the di-bit 00, 01, 11, or 10 for DQPSK modulation. This parameter represents a single symbol which has been demodulated by the PMD entity.

When Generated

This primitive generated by the PMD entity, forwards received data to the PLCP sublayer. The data clock for this primitive is supplied by PMD layer based on the PN code repetition.
Effect of Receipt

The PLCP sublayer either interprets the bit or bits which are recovered as part of the PLCP convergence procedure or pass the data to the MAC layer as part of the MPDU.

### 12.4.5.3. PMDHY_TXE.requestindicate

**Function**

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

**Semantic of the Service Primitive**

The primitive shall provide the following parameters:

\[
\text{PMDHY\_TXE.request(RF\_STATE)}
\]

The RF\_STATE parameter indicates one of two possible PHY operating conditions: Receive or Transmit. This primitive is a Transmit Enable. The default PHY state is receive after power up or after a reset.

**When Generated**

This primitive is generated by the PLCP sublayer to initiate the PMD layer transmission of the PPDU. The PHY\_DATA.request primitive must be provided to the PLCP sublayer prior to setting RF\_STATE = transmit within the PMD\_TXE command.

**Effect of Receipt**

PMD\_TXE initiates or terminates transmission of a PPDU by the PMD sublayer.

### 12.4.5.4. PMD\_ANTSEL.request

**Function**

This primitive, generated by the PHY PLCP sublayer, selects the antenna used by the PHY for transmission or reception (when diversity is disabled).

**Semantic of the Service Primitive**

The primitive shall provide the following parameters:

\[
\text{PMD\_ANTSEL.request(ANT\_STATE)}
\]

ANT\_STATE selects which of the available antennas should be used for transmit. The number of available antenna is determined by the PHY\_INFO parameters NO\_ANT. (Note: receive antenna selection, if any, is a function of the vendor implemented PHY.)

**When Generated**

This primitive is generated by the PLCP sublayer to select a specific antenna for transmission (or reception when diversity is disabled). While not required, multiple antennas can be used to implement a receive antenna diversity scheme. The PMD parameters RSSI and SQ are provided for the optional antenna diversity implementation.
Effect of Receipt

PMD_ANTSEL immediately selects the antenna specified by ANT_STATE.

12.4.5.5.  PMD_ANTSEL.indicate

Function

This primitive, generated by the PHY PLCP sublayer, reports the antenna used by the PHY for reception of the most recent packet.

Semantic of the Service Primitive

The primitive shall provide the following parameters:

PMD_ANTSEL.indicate(ANT_STATE)

ANT_STATE reports which of the available antennas was used for reception of the most recent packet.

When Generated

This primitive is generated by the PLCP sublayer to report the antenna used for the most recent packet reception.

Effect of Receipt

PMD_ANTSEL immediately reports the antenna specified by ANT_STATE.

12.4.5.6.  PMD_DIVERSITY.request

Function

This primitive, generated by the PHY PLCP sublayer, selects whether antenna diversity is enabled or disabled during reception.

Semantic of the Service Primitive

The primitive shall provide the following parameters:

PMD_DIVERSITY.request(DIV_CONTROL)

DIV_CONTROL selects whether the diversity function is enabled or not.

When Generated

This primitive is generated by the PLCP sublayer to change the operating state of the receive state machine to select a specific antenna for reception or to allow diversity function.
Effect of Receipt

PMD_DIVERSITY immediately alters the receive state machine to operate according the DIV_CONTROL.

12.4.5.7. PMD_TXPWRLEVEL.request

Function

This primitive, generated by the PHY PLCP sublayer, selects the power level used by the PHY for transmission.

Semantic of the Service Primitive

The primitive shall provide the following parameters:

PMD_TXPWRLEVEL.request(TXPWR_LEVEL)

TXPWR_LEVEL selects which of the optional transmit power levels should be used for the current packet transmission. The number of available power levels is determined by the MIB parameter NO_TXPWRLEVELS. Section 12.4.7.3 provides further information on the optional DSSS PHY power level control capabilities.

When Generated

This primitive is generated by the PLCP sublayer to select a specific transmit power. This primitive is applied prior to setting PMD_TXE into the transmit state.

Effect of Receipt

PMD_TXPWRLEVEL immediately sets the transmit power level given by TXPWR_LEVEL.

12.4.5.8. PMD_FREQCHANNEL.request

Function

This primitive, generated by the PHY PLCP sublayer, selects the channel frequency which will be used by the DSSS PHY for transmission or reception.

Semantic of the Service Primitive

The primitive shall provide the following parameters:

PMD_FREQCHANNEL.request(CHNL_ID)

CHNL_ID selects which of the DSSS PHY channel frequencies will be used for transmission or reception. Section 12.4.6.2 provides further information on the DSSS PHY channel plan.

When Generated

This primitive is generated by the PLCP sublayer to change or set the current DSSS PHY channel frequency.
Effect of Receipt

The receipt of PMD_FREQCHANNEL immediately changes the frequency-operating channel as set by the CHNL_ID parameter.

12.4.5.9. PMD_RATE.request

Function

This primitive, generated by the PHY PLCP sublayer, selects the modulation RATE which will be used by the DSSS PHY for transmission.

Semantic of the Service Primitive

The primitive shall provide the following parameters:

PMD_RATE.request(RATE)

RATE selects which of the DSSS PHY data rates will be used for MPDU transmission. Section 12.4.6.4 provides further information on the DSSS PHY modulation rates. The DSSS PHY rate change capability is fully described in section 12.2.

When Generated

This primitive is generated by the PLCP sublayer to change or set the current DSSS PHY modulation rate used for the MPDU portion of a PPDU.

Effect of Receipt

The receipt of PMD_RATE selects the rate which will be used for all MPDU transmissions. This rate will be used for transmission only. The DSSS PHY will still be capable of receiving all the required DSSS PHY modulation rates.

12.4.5.10. PMD_RATE.indicate

Function

This primitive, generated by the PMD sublayer, indicates which modulation rate was used to receive the MPDU portion of the PPDU. The modulation is indicated in the PLCP preamble 802.11 SIGNALING field.

Semantic of the Service Primitive

The primitive shall provide the following parameters:

PMD_RATE.indicate(RATE)

In receive mode, the RATE parameter informs the PLCP layer which of the DSSS PHY data rates was used to process the MPDU portion of the PPDU. Section 12.4.6.4 provides further information on the DSSS PHY modulation rates. The DSSS PHY rate change capability is fully described in section 12.2.

When Generated

This primitive is generated by the PMD sublayer when the PLCP preamble 802.11 SIGNALING field has been properly detected.
Effect of Receipt

This parameter is provided to the PLCP layer for information only.

12.4.5.11. **PMD_RSSI.indicate**

**Function**

This primitive, generated by the PMD sublayer, provides to the PLCP and MAC entity the Received Signal Strength.

**Semantic of the Service Primitive**

The primitive shall provide the following parameters:

\[
\text{PMD}_\text{RSSI}.\text{indicate}(\text{RSSI})
\]

The RSSI is a measure of the RF energy received by the DSSS PHY. RSSI indications of up to 8 bits (256 levels) are supported.

**When Generated**

This primitive is generated by the PMD when the DSSS PHY is in the receive state. It is continuously available to the PLCP which in turn provides the parameter to the MAC entity.

**Effect of Receipt**

This parameter is provided to the PLCP layer for information only. The RSSI may be used in conjunction with SQ as part of a Clear Channel Assessment scheme.

12.4.5.12. **PMD_SQ.indicate**

**Function**

This primitive, generated by the PMD sublayer, provides to the PLCP and MAC entity the Signal Quality of the DSSS PHY PN code correlation. The signal quality is sampled when the DSSS PHY achieves code lock and held until the next code lock acquisition.

**Semantic of the Service Primitive**

The primitive shall provide the following parameters:

\[
\text{PMD}_\text{SQ}.\text{indicate}(\text{SQ})
\]

The SQ is a measure of the PN code correlation quality received by the DSSS PHY. SQ indications of up to 8 bits (256 levels) are supported.

**When Generated**

This primitive is generated by the PMD when the DSSS PHY is in the receive state and code lock is achieved. It is continuously available to the PLCP which in turn provides the parameter to the MAC entity.

**Effect of Receipt**
This parameter is provided to the PLCP layer for information only. The SQ may be used in conjunction with RSSI as part of a Clear Channel Assessment scheme. SQ may also be used as a code lock indication based on the SQ_THRESHOLD parameter in section 12.4.5.11.

12.4.5.13. **PMD_CS.indicate**

This primitive, generated by the PMD, indicates to the PLCP layer that the receiver has acquired (locked) the PN code and data is being demodulated.

**Function**

This primitive, generated by the PMD, indicates to the PLCP layer that the receiver has acquired (locked) the PN code and data is being demodulated.

**Semantic of the Service Primitive**

The PMD_CS (Carrier Sense) primitive in conjunction with PMD_ED provide CCA status through the PLCP layer PHY_DATA primitive. PMD_CS indicates a binary status of ENABLED or DISABLED. PMD_CS is ENABLED when the correlator signals quality indicated in PMD_SQ is greater than the CS_THRESHOLD parameter. PHY_CS is DISABLED when the PMD_SQ falls below the correlation threshold.

**When Generated**

This primitive is generated by the PHY sublayer when the PHY is receiving PPDU and the PN code has been acquired.

**Effect of Receipt**

This indicator is provided to the PLCP for forwarding to the MAC entity for information purposes through the PHY_CS indicator. This parameter indicates that the RF media is busy and occupied by a DSSS PHY signal. The DSSS PHY should not be placed into the transmit state when PMD_CS is ENABLED.

12.4.5.14. **PMD_ED.indicate**

**Function**

This primitive, generated by the PMD, indicates to the PLCP layer that the receiver has detected RF energy indicated by the PMD_RSSI primitive which is above a predefined threshold.

**Semantic of the Service Primitive**

The PMD_ED (Energy Detect) primitive along with the PMD_SQ provide CCA status at the PLCP layer through the PHY_DATA primitive. PMD_ED indicates a binary status of ENABLED or DISABLED. PHY_ED is ENABLED when the RSSI indicated in PMD_RSSI is greater than the ED_THRESHOLD parameter. PMD_ED is DISABLED when the PMD_RSSI falls below the energy detect threshold.

**When Generated**

This primitive is generated by the PHY sublayer when the PHY is receiving RF energy from any source which exceeds the ED_THRESHOLD parameter.

**Effect of Receipt**
This indicator is provided to the PLCP for forwarding to the MAC entity for information purposes through the PHY_ED indicator. This parameter indicates that the RF media may be busy with an RF energy source which is not DSSS PHY compliant. If a DSSS PHY source is being received, the PMD_CS function will be enabled shortly after the PMD_ED function is enabled.

12.4.6. PMD Operating Specifications General

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

12.4.6.1. Operating Frequency Range

The DSSS PHY shall operate in the frequency range of 2.4 to 2.4835 GHz as allocated by regulatory bodies in the USA and Europe and in the -2.471 to 2.497 GHz frequency band has been allocated by regulatory authority in Japan.

Additional frequency bands will follow as they are made available.

12.4.6.2. Number of Operating Channels

For the 2.4 to 2.4835 GHz frequency band, 11 channels are specified. The channel center frequencies and CHNL_ID numbers shall be as shown in Table 12.5 for FCC (North America) and ETSI (Europe). For Japan, operation is specified as 2.471 to 2.497 GHz. CHNL_ID 12 is specified for operation in Japan.

<table>
<thead>
<tr>
<th>CHNL_ID</th>
<th>FCC Channel Frequencies</th>
<th>ETSI Channel Frequencies</th>
<th>Japan Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2412 MHz</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>2</td>
<td>2417 MHz</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>3</td>
<td>2422 MHz</td>
<td>2422 MHz</td>
<td>N/A</td>
</tr>
<tr>
<td>4</td>
<td>2427 MHz</td>
<td>2427 MHz</td>
<td>N/A</td>
</tr>
<tr>
<td>5</td>
<td>2432 MHz</td>
<td>2432 MHz</td>
<td>N/A</td>
</tr>
<tr>
<td>6</td>
<td>2437 MHz</td>
<td>2437 MHz</td>
<td>N/A</td>
</tr>
<tr>
<td>7</td>
<td>2442 MHz</td>
<td>2442 MHz</td>
<td>N/A</td>
</tr>
<tr>
<td>8</td>
<td>2447 MHz</td>
<td>2447 MHz</td>
<td>N/A</td>
</tr>
<tr>
<td>9</td>
<td>2452 MHz</td>
<td>2452 MHz</td>
<td>N/A</td>
</tr>
<tr>
<td>10</td>
<td>2457 MHz</td>
<td>2457 MHz</td>
<td>N/A</td>
</tr>
<tr>
<td>11</td>
<td>2462 MHz</td>
<td>2462 MHz</td>
<td>N/A</td>
</tr>
<tr>
<td>12</td>
<td>N/A</td>
<td>N/A</td>
<td>2484 MHz</td>
</tr>
</tbody>
</table>

Table 12-5: DSSS PHY Frequency Channel Plan

In a multiple cell network topology, adjacent cells using different channels can operate simultaneously without interference if the distance between the center frequencies is at least 30 MHz. Channel 12 is designated specifically for operation in Japan.

12.4.6.3. Spreading Sequence

The following 11 chip Barker sequence shall be used as the PN code sequence:

\[ +1, -1, +1, +1, -1, +1, +1, -1, -1, -1 \]
The left most chip is output first in time. The first chip is aligned as the start of a transmitted symbol. The symbol duration is exactly 11-chips long.

12.4.6.4. Modulation and Channel Data Rates

Two modulation formats and data rates are specified for the DSSS PHY: a Basic Access Rate and an Enhanced Access Rate. The Basic Access Rate is based on 1 Mb/s BPS DBPSK modulation. The DBPSK encoder is specified in Table 12.6. The Enhanced Access Rate is based on 2 Mb/s BPS DQPSK. The DQPSK encoder is specified in Table 12.7. (In the tables, $+j\omega$ is defined as counterclockwise rotation.)

<table>
<thead>
<tr>
<th>Bit Input</th>
<th>Phase Change ($+j\omega$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>$\pi$</td>
</tr>
</tbody>
</table>

Table 12-6: 1 Mb/s BPS DBPSK Encoding Table

<table>
<thead>
<tr>
<th>Dibit pattern $(d_0,d_1)$</th>
<th>Phase Change ($+j\omega$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$d_0$ is first in time</td>
<td></td>
</tr>
<tr>
<td>00</td>
<td>0</td>
</tr>
<tr>
<td>01</td>
<td>$\pi/2$</td>
</tr>
<tr>
<td>11</td>
<td>$\pi$</td>
</tr>
<tr>
<td>10</td>
<td>$3\pi/2$ ($-\pi/2$)</td>
</tr>
</tbody>
</table>

Table 12-7: 2 Mb/s BPS DQPSK Encoding Table

12.4.6.5. Transmit and Receive In Band and Out of Band Spurious Emissions

The DSSS PHY shall conform with in band and out of band spurious emissions as set by regulatory bodies in the USA and Europe. For the USA, refer to FCC 15.247, 15.205, and 15.209. For Europe, refer to ETS 300-328.

12.4.6.6. Transmit to Receive Turnaround Time

The TX to RX turnaround time shall be less than 10 usec including the power down ramp specified in section 12.4.7.7.

The TX to RX turnaround time shall be measured at the air interface from the trailing edge of the last transmitted symbol to valid CCA. The CCA should occur within 25 usec (10 usec for turnaround time plus 15 usec for energy detect) or by the next slot boundary occurring after the 25 usec has elapsed (refer to 12.4.8.4). A receiver input signal 3dB above the ED threshold described in section 12.4.8.4 shall be present at the receiver.

12.4.6.7. Receive to Transmit Turnaround Time

The RX to TX turnaround time is measured at the MAC/IPHY interface, using PHY_DATA.request(start_of_data) and shall be less than or equal to 5 usec. This includes the transmit power up ramp described in section 12.4.8.6.

12.4.6.8. Slottime

The slot time for the DSSS PHY is the sum of the RX to TX turnaround time (5 usec) and the energy detect time (15 usec specified in section 12.4.8.4). The propagation delay, which is in the order of 1 usec, is regarded to be included in the energy detect time.
12.4.6.9. Transmit and Receive Antenna Port Impedance
The transmit and receive antenna port(s) impedance shall be 50Ω if the port is exposed.

12.4.6.10. Transmit and Receive Operating Temperature Range
Two temperature ranges for full operation compliance to the DSSS PHY are specified. Type 1 is defined as 0°C to 40°C and is designated for office environments. Type 2 is defined as -30°C to +70°C and is designated for industrial environments.

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

12.4.7.1. Transmit Power Levels
The maximum Equivalent Isotropically Radiated Power (EIRP) as measured in accordance with practices specified by the regulatory bodies is shown in Table 12-8. In the USA, the radiated emissions should also conform with the ANSI uncontrolled radiation emission standards (ANSI document C95.1 published in 1991).

<table>
<thead>
<tr>
<th>Maximum EIRP</th>
<th>Geographic Location</th>
<th>Compliance Document</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000 mW</td>
<td>USA</td>
<td>FCC 15.247</td>
</tr>
<tr>
<td>100 mW</td>
<td>EUROPE</td>
<td>ETS 300-328</td>
</tr>
<tr>
<td>10 mW/MHz</td>
<td>JAPAN</td>
<td>MPT ordinance 78</td>
</tr>
</tbody>
</table>

Table 12-8: Transmit Power Levels

12.4.7.2. Minimum Transmitted Power Level
The minimum transmitted power shall be no less than 1 mW.

12.4.7.3. Transmit Power Level Control
Power control shall be provided for transmitted power greater than 100 mW. A maximum of 4 power levels may be provided. At a minimum, a radio capable of transmission greater than 100 mW shall be capable of switching power back to 100 mW or less.

12.4.7.4. Transmit Spectrum Mask
The transmitted spectral products shall be less than -30 dBμr (dB relative to the SIN^2x peak) for \( f_{c} - 22 \) MHz < \( f < f_{c} - 11 \) MHz and \( f > f_{c} + 22 \) MHz where \( f_{c} \) is the channel center frequency. The transmitted spectral mask is shown in figure 12-10. The measurements shall be made using 100 KHz resolution bandwidth.
12.4.7.5. Transmit Center Frequency Tolerance

The transmitted center frequency tolerance is +/- 25 ppm maximum.

12.4.7.6. Chip Clock Frequency Tolerance

The PN code chip clock frequency tolerance shall be better than +/- 25 ppm maximum.

12.4.7.7. Transmit Power On and Power Down Ramp

The transmit power on ramp for 10% to 90% of maximum power shall be no greater than 2 usec. The transmit power on ramp is shown in figure 12-11.

The transmit power down ramp for 90% to 10% maximum power shall be no greater than 2 usec. The transmit power down ramp is shown in figure 12-12.
The transmit power ramps shall be constructed such that the DSSS PHY emissions conform with spurious frequency product specification defined in section 12.4.6.5.

12.4.7.8. RF Carrier Suppression

The RF carrier suppression, measured at the channel center frequency, shall be at least 15 dB below the peak SIN(x)/x power spectrum. The RF carrier suppression shall be measured while transmitting a repetitive 01 data sequence with the scrambler disabled using DQPSK modulation. A 100 KHz resolution bandwidth shall be used to perform this measurement.

12.4.7.9. Transmit Modulation Accuracy

The transmit modulation accuracy requirement for the DSSS PHY is based on the difference between the actual transmitted waveform and the ideal signal waveform. Modulation accuracy shall be determined by measuring the peak vector error magnitude measured during each chip period. Worst case vector error magnitude shall not exceed 0.35 for the normalized sampled chip data. The ideal complex I and Q constellation points associated with DQPSK modulation (0.707,0.707), (0.707,-0.707), (-0.707, 0.707), (-0.707, -0.707) shall be used as the reference. These measurements shall be from baseband I and Q sampled data after recovery through a reference receiver system.

Figure 12-13 illustrates the ideal DQPSK constellation points and range of worst case error specified for modulation accuracy.
Error vector measurement requires a reference receiver capable of carrier lock. All measurements shall be made under carrier lock conditions. The distortion induced in the constellation by the reference receiver shall be calibrated and measured. The test data error vectors described below will be corrected to compensate for the reference receiver distortion.

The 802.11 vendor compatible radio shall provide an exposed TX chip clock which is used to sample the I and Q outputs of the reference receiver.

The measurement is made under the conditions of continuous DQPSK transmission using scrambled all 1's.

The EYE pattern of the I channel will be used to determine the I and Q sampling point. The chip clock provided by the vendor radio will be time delayed such that the samples fall at a 1/2 chip period offset from the mean of the zero crossing positions of the EYE (see figure 12-14 below). This is the ideal center of the EYE and may not be the point of maximum EYE OPENING.
Using the aligned chip clock, 1000 samples of the I and Q baseband outputs from the reference receiver are captured. The vector error magnitudes shall be calculated as follows:

Calculate the DC offsets for I and Q samples.

\[ I_{\text{mean}} = \sum_{n=0}^{1000} I(n)/1000 \]
\[ Q_{\text{mean}} = \sum_{n=0}^{1000} Q(n)/1000 \]

Calculate the DC corrected I and Q samples for all \( N = 1000 \) samples pairs.

\[ I_{\text{DC}}(n) = I(n) - I_{\text{mean}} \]
\[ Q_{\text{DC}}(n) = Q(n) - Q_{\text{mean}} \]

Calculate the average magnitude of I and Q samples.

\[ I_{\text{mag}} = \sum_{n=0}^{1000} I_{\text{DC}}(n)/1000 \]
\[ Q_{\text{mag}} = \sum_{n=0}^{1000} Q_{\text{DC}}(n)/1000 \]

Calculate the normalized error vector magnitude for the \( I_{\text{DC}}(n)/Q_{\text{DC}}(n) \) pairs.

\[ V_{\text{ERR}}(n) = \sqrt{1/2 \times (I_{\text{DC}}(n)/I_{\text{mag}})^2 + (Q_{\text{DC}}(n)/Q_{\text{mag}})^2} - V_{\text{CORRECTION}} \]

with \( V_{\text{CORRECTION}} = \) error induced by the reference receiver system

A vendor DSSS PHY implementation shall be compliant if for all \( N = 1000 \) samples the following condition is met:

Submission Page 3691332 DS-PHY (Mike Trompower, Aironet)
12.4.8.1. **PMD Receiver Specifications**

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

12.4.8.1. **Receiver Minimum Input Level Sensitivity**

The Frame Error Rate (FER) shall be less than $8 \times 10^{-3}$ at a Frame length of 1024 bytes for an input level of -80 dBm measured at the antenna connector. This FER is specified for 2 Mb/s BPS DQPSK modulated with the 11 chip Barker spreading sequence. The test for the minimum input level sensitivity shall be conducted with the energy detection threshold set less than or equal to -80 dBm.

12.4.8.2. **Receiver Maximum Input Level**

The receiver shall provide a maximum FER of $8 \times 10^{-3}$ at a maximum input level of -4 dBm measured at the antenna. This FER is specified for 2 Mb/s BPS DQPSK modulated with the 11 chip Barker spreading sequence.

12.4.8.3. **Receiver Adjacent Channel Rejection**

Adjacent channel rejection is defined between the two channels in each channel group defined in section 12.4.6.2.

The adjacent channel rejection shall be equal to or better than 35 dB with a FER of $8 \times 10^{-3}$ using 2 Mb/s BPS DQPSK modulated with the 11 chip Barker spreading code.

The adjacent channel rejection shall be measured using the following method:

- Input a 2 Mb/s BPS DQPSK signal spread with the 11 chip Barker spreading code at a level 6 dB greater than specified in section 12.4.8.1. In an adjacent channel (greater than 30 MHz separation as defined by the channel numbering), input a signal modulated in a similar fashion which adheres to the transmit mask specified in section 12.4.7.3 to a level 41 dB above the level specified in 12.4.8.1. The adjacent channel signal must be derived from a separate signal source. It cannot be a frequency shifted version of the reference channel. Under these conditions, the FER shall be no worse than $8 \times 10^{-3}$.

12.4.8.4. **Clear Channel Assessment**

The DSSS PHY shall provide the capability to perform Clear Channel Assessment (CCA).

The CCA shall be based on the status of energy detection above a given threshold and by detection of code lock based on correlation quality (i.e. carrier sense). The energy detection status is given by PMD primitive, PMD_ED. The carrier sense status is given by PMD_CS. The status of PMD_ED and PMD_CS are used in the PLCP convergence procedure to indicate activity to the MAC through the PHY interface primitive PHY_DATA.indicate. The primitive class indicates the CCA status.

A Busy channel is indicated by PHY_DATA.indicate of class START-OF-ACTIVITY, END-OF-DATA, or DATA.

Clear Channel is indicated by PHY_DATA.indicate of class END-OF-DATA-AND-ACTIVITY or END-OF-ACTIVITY.
The CCA shall be TRUE if there is no energy detect or carrier sense. If ED is active for a period of 22 ms with or without carrier sense being active, then CCA is allowed to go TRUE until a positive change in energy detect or carrier sense or a transmit to receive condition as described below in (e). The CCA parameters are subject to the following criteria:

a) The energy detection threshold shall be less than or equal to -80 dBm for TX power > 100 mW, -76 dBm for 50 mW < TX power <= 100 mW, and -70 dBm <= 50 mW.

b) The worst case latency of the detection of an energy change across the ED threshold incident on the receiver antenna to the reporting of channel busy shall be less than or equal to 15 usec or by the next slot boundary occurring after the 15 usec has elapsed. This implies that the CCA signal is available as an exposed test point.

c) The CCA state machine shall be reset upon transition from the TX state to the RX state.

Conformance to DSSS PHY CCA shall be demonstrated by applying a DSSS compliant signal (continuous and pulsed CW (above and below the appropriate energy detect threshold)) and DS PHY compliant signals such that all conditions described above are demonstrated.
## Appendix A. MIB Value Table

<table>
<thead>
<tr>
<th>Managed Object</th>
<th>Default Value / Range</th>
<th>Operational Semantics</th>
</tr>
</thead>
<tbody>
<tr>
<td>agPhyOperation_grp</td>
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<tr>
<td>aPHY_Type</td>
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