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Wireless LANs

Draft Specifications of Carrier Frequency Offset-Spread Spectrum Physical Layer for the 2.4 GHz ISM Band

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1 Introduction

This clause describes the physical layer for the Carrier Frequency Offset- Spread Spectrum (CFO-SS) system. The CFO-SS system is aimed for the high speed PHY for 2.4 GHz ISM band as provided in the USA according to Document FCC 15.247, in Europe by ETS 300-328 and other countries according to clause 4.6.2.

The CFO-SS system provides a wireless LAN with 1 Mbit/s, 2 Mbit/s, 4 Mbit/s, 6 Mbit/s, 8 Mbit/s and 10 Mbit/s data payload communication capability. According to the FCC regulations, the CFO-SS system shall provide a processing gain of at least 10 dB. This shall be accomplished by chipping the baseband signal of each channel at 11 MHz with an 11-chip PN code. The CFO-SS system uses baseband modulations of Differential Binary Phase Shift Keying (DBPSK) and the multiple channels of Differential Quadrature Phase Shift Keying (DQPSK) to provide the 1, 2, 4, 6, 8, 10 Mbit/s data rates, respectively.

1.1 Scope

This clause describes the physical layer services provided to the 802.11 wireless LAN MAC by the 2.4 GHz CFO-SS system. The CFO-SS 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 shall be 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 stations each using the CFO-SS system.

1.2 CFO-SS Physical Layer Functions

The 2.4 GHz CFO-SS PHY architecture is depicted in the reference model shown in Figure 11 in P802.11D6.1. The CFO-SS 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 subclauses.

The CFO-SS Physical Layer service shall be provided to the Media Access Control through the physical layer service primitives described in clause 12 in P802.11D6.1.

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.

1.2.2 Physical Medium Dependent Sublayer

The physical medium dependent sublayer provides a means to send and receive data between two or more stations. This clause is concerned with the 2.4 GHz ISM bands using Synchronous Multicarrier Direct Sequence modulation for CFO-SS scheme.

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.

1.3 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, an example method of implementation is left to the discretion of the 802.11 High Speed 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.

2 CFO-SS Physical Layer Convergence Procedure Sublayer

2.1 Introduction

This clause provides a convergence procedure in which MPDUs are converted to and from PPDUs. During transmission, the MPDU shall be 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.

2.2 Physical Layer Convergence Procedure Frame Format

Figure 1 shows the format for the PPDU including the CFO-SS PLCP preamble, the CFO-SS 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), and CCITT CRC-16. Each of these fields- are described in detail in clause 2.3.

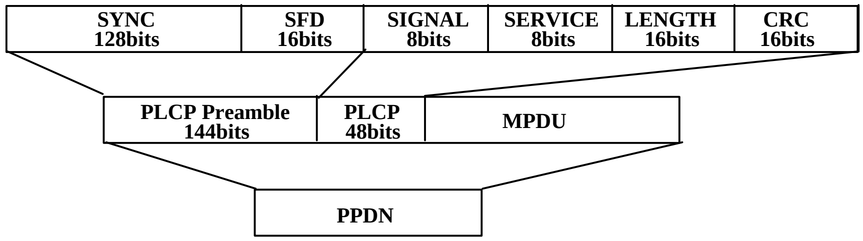

Figure 1, PLCP Frame Format

2.3 PLCP Field Definitions

The entire PLCP preamble and header of multiple channels shall be transmitted using the 1 Mbit/s DBPSK modulation described in clause 4.7. All transmitted bits shall be scrambled using the feedthrough scrambler described in clause 2.4.

2.3.1 PLCP Synchronization (SYNC)

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

2.3.2 PLCP Start Frame Delimiter (SFD)

The Start Frame Delimiter shall be provided to indicate the start of PHY dependent parameters within the PLCP preamble. The SFD shall be a 16 bit field, F3A0h (MSB to LSB). The LSB shall be transmitted first in time.

2.3.3 PLCP 802.11 Signal Field (SIGNAL)

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

a) 0Ah (MSB to LSB) for 1 Mbit/s DBPSK
b) 14h (MSB to LSB) for 2 Mbit/s DQPSK
c) 28h for two channel multiplexed 4 Mbit/s CFO-SS
d) 3Ch for three channel multiplexed 6 Mbit/s CFO-SS
e) 50h for four channel multiplexed 8 Mbit/s CFO-SS
f) 64h for five channel multiplexed 10 Mbit/s CFO-SS

The CFO-SS PHY rate change capability is described in clause 2.5. This field shall be protected by the CCITT CRC-16 frame check sequence described in clause 2.3.6.

2.3.4 PLCP 802.11 Service Field (SERVICE)

The 8 bit 802.11 service field shall be reserved for future use. The value of 00h signifies 802.11 device compliance. The LSB shall be transmitted first in time. This field shall be protected by the CCITT CRC-16 frame check sequence described in clause 2.3.6.

2.3.5 PLCP Length Field (LENGTH)

The PLCP length field shall be an unsigned 16 bit integer which indicates the number of microseconds (16 to $2^{16}-1$ as defined by aMPDUMaxLngth) required to transmit the MPDU. The transmitted value shall be determined from the LENGTH parameter in the TXVECTOR issued with the PHY_TXSTART.request primitive described in clause 12.3.5.4. of P802.11D6.1. The length field provided in the TXVECTOR is in bytes and is converted to microseconds for inclusion in the PLCP LENGTH field. The LSB (least significant bit) shall be transmitted first in time. This field shall be protected by the CCITT CRC-16 frame check sequence described in clause 2.3.6.

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 shall be 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 shall be processed in transmit order. All FCS calculations shall be made prior to data scrambling.

2.4 PLCP / CFO-SS PHY Data Scrambler and Descrambler

The polynominal $G(z) = z^{-7} + z^{-4} + 1$ shall be used to scramble ALL bits transmitted by the CFO-SS PHY. The feedthrough configuration of the scramble and descrambler is self synchronizing which requires no prior knowledge of the transmitter initialization of the scrambler for receive processing.

The scrambler should be initialized to any state except all ones when transmitting.

2.5 PLCP Data Modulation and Modulation Rate Change

The PLCP preamble shall be transmitted using the 1 Mbit/s DBPSK modulation of backward compatible channel. The other channels could be transmitted using the same DBPSK modulation with specified preamble patterns. The 802.11 SIGNAL field shall indicate the transmission rate which shall be used to transmit the MPDU. The transmitter and receiver shall initiate the modulation and active channel numbers indicated by the 802.11 SIGNAL field starting with the first symbol (1bit for DBPSK or 2 bits for DQPSK) of the MPDU. The MPDU transmission rate shall be set by the DATARATE parameter in the TXVECTOR issued with the PHY_TXSTART.request primitive described in clause 4.4.1.

2.6 PLCP Transmit Procedure

In order to transmit data, PHY_TXSTART.request shall be enabled so that the PHY entity shall be in the transmit state. Further, the PHY shall be set to operate at the appropriate channel through Station Management via the PLME. Other transmit parameters such as DATARATE, TX antenna, and TX power are set via the PHY-SAP with the TXSTART.request(TXVECTOR) as described in clause 4.4.2.

Based on the status of CCA indicated by PHY_CCA.indicate, the MAC will assess that the channel is clear. A clear channel shall be indicated by PHY_CCA.indicate(IDLE). If the channel is clear, transmission of the PPDU shall be initiated by issuing the PHY_TXSTART.request (TXVECTOR) primitive. The TXVECTOR elements for the PHY_TXSTART.request are the PLCP header parameters SIGNAL, SERVICE and LENGTH and the PMD parameters of TX_ANTENNA, and TXPWR_LEVEL. The PLCP header parameter LENGTH is calculated from the TXVECTOR element by multiplying 8 for 1 Mbit/s, by 4 for 2 Mbit/s, by 2 for 4 Mbit/s, by 1.333 for 6 Mbit/s, 1 for 8 Mbit/s and by 0.8 for 10 Mbit/s.

The PLCP shall issue PMD_ANTSEL, PMD_RATE, and PMD_TXPWRLVL primitives to configure the PHY. The PLCP shall then issue a PMD_TXSTART.request and the PHY entity shall immediately initiate data scrambling and transmission of the PLCP preamble based on the parameters passed in the PHY_TXSTART.request primitive. The time required for TX power on ramp described in clause 4.7.7 shall be included in the PLCP synchronization field. Once the PLCP preamble transmission is complete, data shall be exchanged between the MAC and the PHY by a series of PHY_DATA.request(DATA) primitives issued by the MAC. The modulation rate change, if any, shall be initiated with the first data symbol of the MPDU as described in clause 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 can be prematurely terminated by the MAC through the primitive PHY_TXEND.request. PHY_TXSTART shall be disabled by the issuance of the PHY_TXEND.request. Normal termination occurs after the transmission of the final bit of the last MPDU octet according to the number supplied in the CFO-SS PHY preamble LENGTH field. The packet transmission shall be completed and the PHY entity shall enter the receive state (i.e. PHY_TXSTART shall be disabled). It is recommended that chipping continue during power down. Each PHY-TXEND.request is acknowledged with a PHY-TXEND.confirm primitive from the PHY.

2.7 PLCP Receive Procedure

In order to receive data, PHY_TXSTART.request shall be disabled so that the PHY entity is in the receive state. Further, through Station Management via the PLME, the PHY is set to the appropriate CHNL_ID and the CCA method is chosen. Other receive parameters such as RSSI, SQ (signal quality), and indicated DATARATE may be accessed via the PHY-SAP.

Upon receiving the transmitted energy, according to the selected CCA mode, the PMD_ED shall be enabled (according to clause 4.8.4) as the RSSI strength reaches the ED_THRESHOLD and/or PMD_CS shall be enabled after code lock is established. These conditions are used to indicate activity to the MAC via PHY_CCA.indicate according to clause 4.8.4. PHY_CCA.indicate(BUSY) shall be issued for energy detection and/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.

After PHY_CCA.indicate is issued, the PHY entity shall begin searching for the SFD field. Once the SFD field is detected, CCITT CRC-16 processing shall be initiated and the PLCP 802.11 SIGNAL, 802.11 SERVICE, and LENGTH fields are received. The CCITT CRC-16 FCS shall be processed. If the CCITT CRC-16 FCS check fails, the PHY receiver shall return to the RX Idle state.
Should the status of CCA return to the IDLE state during reception prior to completion of the full PLCP processing, the PHY receiver shall return to the RX Idle state.

If the PLCP header reception is successful (and the SIGNAL field is completely recognizable and supported), a PHY_RXSTART.indicate(RXVECTOR) shall be issued. The RXVECTOR associated with this primitive includes the SIGNAL field, the SERVICE field, the MPDU length in bytes (calculated from the LENGTH field in microseconds), the antenna used for receive, PHY_RSSI, and PHY_SQ.

The received MPDU bits are assembled into octets and presented to the MAC using a series of PHY_DATA.indicate(DATA) primitive exchanges. The rate change indicated in the 802.11 SIGNAL field shall be initiated with the first symbol of the MPDU as described in clause 2.5. The PHY proceeds with MPDU reception. After the reception of the final bit of the last MPDU octet indicated by the PLCP preamble LENGTH field, the receiver shall be returned to the RX Idle state. A PHY_RXEND.indicate(NoError) primitive shall be issued. A PHY_CCA.indicate(IDLE) primitive shall be issued following a change in PHY_CS and/or PHY_ED according to the selected CCA method.

In the event that a change in PHY_CS or PHY_ED would cause the status of CCA to return to the IDLE state before the complete reception of the MPDU as indicated by the PLCP LENGTH field, the error condition PHY_RXEND.indicate(carrierLost) shall be reported to the MAC. The CFO-SS PHY shall ensure that the CCA shall indicate a busy medium for the intended duration of the transmitted packet.

If the PLCP header is successful, but the indicated rate in the SIGNAL field is not receivable, a PHY_RXSTART.indicate will not be issued. The PHY shall issue the error condition PHY RXEND.indicate(UnsupportedRate). If the PLCP header is successful, but the SERVICE field is out of 802.11 CFO-SS specification, a PHY-RXSTART.indicate will not be issued. The PHY shall issue the error condition PHY-

RXEND.indicate(FormatViolation). Also, in both cases, the CFO-SS PHY will ensure that the CCA shall indicate a busy medium for the intended duration of the transmitted frame as indicated by the LENGTH field. The intended duration is indicated by the LENGTH field (length * 1 microseconds).

3 CFO-SS Physical Layer Management Entity (PLME)

3.1 PLME_SAP Sublayer Management primitives

Table 1 lists the MIB attributes which may be accessed by the PHY sublayer entities and intra layer of higher Layer Management Entities (LME). These attributes are accessed via the PLME-GET, PLME-SET and PLME-RESET primitives defined in clause 10 of P802.11D6.1.

3.2 CFO-SS Physical Layer Management Information Base

All CFO-SS Physical Layer Management Information Base attributes are defined in clause 12 of P802.11D6.1. with specific values.

4 CFO-SS Physical Medium Dependent Sublayer

4.1 Scope and Field of Application

This clause describes the PMD services provided to the PLCP for the CFO-SS Physical Layer. Also defined in this clause are the functional, electrical, and RF characteristics required for interoperability of implementations conforming to this specification. The relationship of this specification to the entire CFO-SS PHY Layer is shown in Figure 2.

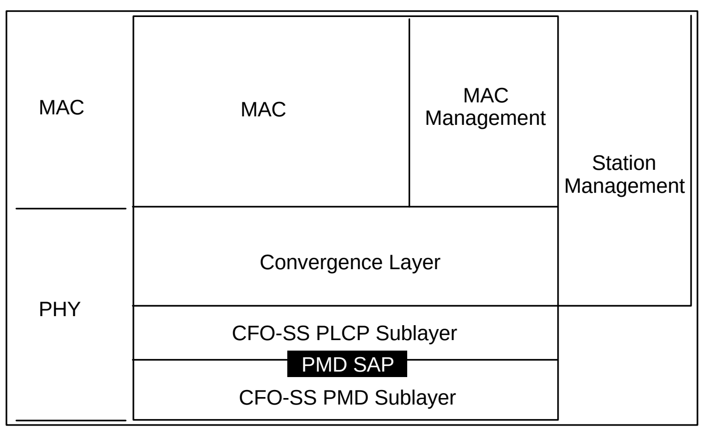

Figure 2, PMD Layer Reference Model

4.2 Overview of Service

The CFO-SS Physical Medium Dependent Sublayer accepts Physical Layer Convergence Procedure sublayer service primitives and provides the actual means by which data shall be transmitted or received from the media. The combined function of CFO-SS 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 functionality shall be provided for data transmission.

4.3 Overview of Interactions

The primitives associated with the 802.11 PLCP sublayer to the CFO-SS 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.

4.4 Basic Service and Options

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

4.4.1 PMD_SAP Peer-to-Peer Service Primitives

4.4.2 PMD_SAP Peer-to-Peer Service Primitive Parameters

Several service primitives include a parameter vector. This vector shall be actually a list of parameters which may vary depending on PHY type.

4.4.3 PMD_SAP Sublayer-to-Sublayer Service Primitives

4.4.4 PMD_SAP Service Primitive Parameters

Parameter	Associate Primitive	Value
DATA	PHY-DATA.request PHY-DATA.indicate	octet value:00h-FFh
TXVECTOR	PHY-DATA.request	a set of parameters
RXVECTOR	PHY-DATA.indicate	a set of parameters
TXD-UNIT	PMD-DATA.request	One(1), Zero(0): DBPSK di bit combinations 00, 01, 11, 10: DQPSK
RXD-UNIT	PMD-DATA.indicate	One(1), Zero(0): DBPSK di bit combinations 00, 01, 11, 10: DQPSK
RF-STATE	PMD-TXT.request	Receive, Transmit
ANT-STATE	PMD-ANTSEL.indicate PMD-ANTSEL.request	1 to 256
TXPWR-LEVEL	PHY-TXSTART	0, 1, 2, 3 (max of 4 level)
RATE	PMD-RATE.indicate PMD-RATE.request	0Ah for 1 Mbit/s DBPSK 14h for 2 Mbit/s DQPSK 28h for two channel multiplexed 4 Mbit/s CFO-SS 3Ch for three channel multiplexed 6 Mbit/s CFO-SS 50h for four channel multiplexed 8 Mbit/s CFO-SS 64h for five channel multiplexed 10 Mbit/s CFO-SS
RSSI	PMD-RSSI.indicate	0-8 bits of RSSI
SQ	PMD-SQ.indicate	0-8 bits of signal Quality

Table 1, List of Parameters for the PMD Primitives

4.5 PMD_SAP Detailed Service Specification

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

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:

PMD_DATA.request(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 and each DQPSK modulation of 4 Mbit/s~10 Mbit/s CFO-SS systems. This parameter represents a single block of data which in turn shall be used by the PHY to be differentially encoded into a DBPSK or DQPSK transmitted symbol. The symbol itself shall be spread by the PN code prior to transmission.

When Generated

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

Effect of Receipt

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

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:

PMD_DATA.indicate(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 and each DQPSK modulation of 4 Mbit/s~10 Mbit/s CFO-SS systems..@.@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 shall be 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.

4.5.3 PMD_TXSTART.request

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:

PMD_TXSTART.request

When Generated

This primitive shall be generated by the PLCP sublayer to initiate the PMD layer transmission of the PPDU. The PHY_DATA.request primitive shall be provided to the PLCP sublayer prior to issuing the PMD_TXSTART command.

Effect of Receipt

PMD_TXSTART initiates transmission of a PPDU by the PMD sublayer.

4.5.4 PMD_TXEND.request

Function

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

Semantic of the Service Primitive

The primitive shall provide the following parameters:

PMD_TXEND.request

When Generated

This primitive shall be generated by the PLCP sublayer to terminate the PMD layer transmission of the PPDU.

Effect of Receipt

PMD_TXEND terminates transmission of a PPDU by the PMD sublayer.

4.5.5 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:

PMD_ANTSEL.request(ANT_STATE)

ANT_STATE selects which of the available antennas should be used for transmit. The number of available antennas shall be determined from the MIB table parameters aSuprtRxAntennas and aSuprtTxAntennas.

When Generated

This primitive shall be generated by the PLCP sublayer to select a specific antenna for transmission (or reception when diversity is disabled).

Effect of Receipt

PMD_ANTSEL immediately selects the antenna specified by ANT_STATE.

4.5.6 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 shall be 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.

4.5.7 PMD_TXPWRLVL.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_TXPWRLVL.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 shall be determined by the MIB parameter NO_TXPWRLVLS. Clause 4.7.3 provides further information on the optional CFO-SS PHY power level control capabilities.

When Generated

This primitive shall be generated by the PLCP sublayer to select a specific transmit power. This primitive shall be applied prior to setting PMD_TXSTART into the transmit state.

Effect of Receipt

PMD_TXPWRLVL immediately sets the transmit power level given by TXPWR_LEVEL.

4.5.8 PMD_RATE.request

Function

This primitive, generated by the PHY PLCP sublayer, selects the modulation RATE which shall be used by the CFO-SS PHY for transmission.

Semantic of the Service Primitive

The primitive shall provide the following parameters:

PMD_RATE.request(RATE)

RATE selects which of the CFO-SS PHY data rates shall be used for MPDU transmission. Clause 4.6.4 provides further information on the CFO-SS PHY modulation rates. The CFO-SS PHY rate change capability is fully described in clause 2.

When Generated

This primitive shall be generated by the PLCP sublayer to change or set the current CFO-SS PHY modulation rate used for the MPDU portion of a PPDU.

Effect of Receipt

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

4.5.9 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 shall be 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 CFO-SS PHY data rates was used to process the MPDU portion of the PPDU. Clause 4.6.4 provides further information on the CFO-SS PHY modulation rates. The CFO-SS PHY rate change capability is fully described in clause 2.

When Generated

This primitive shall be generated by the PMD sublayer when the PLCP preamble 802.11 SIGNALING field has been properly detected.

Effect of Receipt

This parameter shall be provided to the PLCP layer for information only.

4.5.10 PMD_RSSI.indicate

Function

This optional 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:

PMD_RSSI.indicate(RSSI)

The RSSI shall be a measure of the RF energy received by the CFO-SS PHY. RSSI indications of up to 8 bits (256 levels) are supported.

When Generated

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

Effect of Receipt

This parameter shall be 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.

4.5.11 PMD_SQ.indicate

Function

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

Semantic of the Service Primitive

The primitive shall provide the following parameters:

PMD_SQ.indicate(SQ)

The SQ shall be a measure of the PN code correlation quality received by the CFO-SS PHY. SQ indications of up to 8 bits (256 levels) are supported.

When Generated

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

Effect of Receipt

This parameter shall be 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.

4.5.12 PMD_CS.indicate

This primitive, generated by the PMD, shall indicate 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, shall indicate 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 PHYCCA primitive. PMD_CS indicates a binary status of ENABLED or DISABLED.
PMD_CS shall be ENABLED when the correlator signals quality indicated in PMD_SQ is greater than the CS_THRESHOLD parameter. PMD_CS shall be DISABLED when the PMD_SQ falls below the correlation threshold.

When Generated

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

Effect of Receipt

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

4.5.13 PMD_ED.indicate

Function

This optional primitive, generated by the PMD, may indicate 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_CCA primitive. PMD_ED indicates a binary status of ENABLED or DISABLED. PMD_ED shall be ENABLED when the RSSI indicated in PMD_RSSI is greater than the ED_THRESHOLD parameter. PMD_ED shall be DISABLED when the PMD_RSSI falls below the energy detect threshold.

When Generated

This primitive shall be 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 shall be provided to the PLCP for forwarding to the MAC entity for information purposes through the PMD_ED indicator. This parameter shall indicate that the RF media may be busy with an RF energy source which is not CFO-SS PHY compliant. If a CFO-SS PHY source is being received, the PMD_CS function shall be enabled shortly after the PMD_ED function is enabled.

4.5.14 PMD_ED.request

Function

This optional primitive, generated by the PHY PLCP, sets the energy detect ED THRESHOLD value.

Semantics of the Service Primitive

The primitive shall provide the following parameters:

PMD_ED.request(ED_THRESHOLD)

ED_THRESHOLD sets the threshold which the RSSI indicated shall be greater than in order for PMD_ED to be enabled.

When Generated

This primitive shall be generated by the PLCP sublayer to change or set the current CFO-SS PHY energy detect threshold.

Effect of Receipt

The receipt of PMD_ED immediately changes the energy detection threshold as set by the ED_THRESHOLD parameter.

4.5.15 PHY_CCA.indicate

Function

This primitive, generated by the PMD, indicates to the PLCP layer that the receiver has detected RF energy which adheres to the CCA algorithm.

Semantic of the Service Primitive

The PHY-CCA primitive provides CCA status at the PLCP layer to the MAC.

When Generated

This primitive shall be generated by the PHY sublayer when the PHY is receiving RF energy from any source which exceeds the ED_THRESHOLD parameter (PMD_ED is active) and optionally is a valid correlated CFO-PHY signal whereby PMD_CS would also be active.

Effect of Receipt

This indicator shall be provided to the PLCP for forwarding to the MAC entity for information purposes through the PHY-CCA indicator. This parameter indicates that the RF media may be busy with an RF energy source which may or may not be CFO-SS PHY compliant. If a CFO-SS PHY source is being received, the PMD_CS function shall be enabled shortly after the PMD_ED function is enabled.

4.6 PMD Operating Specifications General

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

4.6.1 Operating Frequency Range

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

4.6.2 Number of Operating Channels

For the 2.4 to 2.4835 GHz frequency band, 11 channels are specified for the current low rate PHY. The channel center frequencies and CHNL_ID numbers shall be as shown in Table 2 for FCC and IC (North America) and ETSI (Europe). For Japan, operation shall be specified as 2.471 to 2.497 GHz. CHNL_ID 12 shall be specified for operation in Japan. For the FCC and IC domains all channels 1-11 shall be supported and for the ETSI domain channels 3-11 shall be supported.
For the 10 Mbit/s CFO-SS PHY, three center frequencies for rigid channelization plan and candidate channels for flexible channelization plan are specified in the same table.

		Regulatory Domains					
CHNL-ID	Frequency	10h FCC	20h IC	30h ETSI	CFO-SS Rigid channelization plan	CFO-SS Flexible channelization plan	40h MKK
1	2412MHz	X	X	X	-	X	-
	2414MHz	-	-	-	X	-	-
2	2417MHz	X	X	X	-	X	-
3	2422MHz	X	X	X	-	X	-
4	2427MHz	X	X	X	-	X	-
5	2432MHz	X	X	X	-	X	-
6	2437MHz	X	X	X	-	X	-
7	2442MHz	X	X	X	X	X	-
8	2447MHz	X	X	X	-	X	-
9	2452MHz	X	X	X	-	X	-
10	2457MHz	X	X	X	-	X	-
11	2462MHz	X	X	X	-	X	-
12	2467MHz	-	-	X	-	-	-
	2470MHz	-	-	-	X	-	-
13	2472MHz	-	-	X	-	-	-

14	2484MHz	-	-	-	X	X	X

Table 2, CFO-SS PHY Frequency Channel Plan

In a multiple cell network topology, overlapping and/or adjacent cells using different channels can operate simultaneously without interference by selecting an appropriate channel separation. For the rigid channelization plan, the separation between the center frequencies is 28 MHz, which is sufficient to avoid the interference from the adjacent channels. When the flexible channelization plan is employed, the distance between the center frequencies should be 30 MHz.
Channel 12 shall be designated specifically for operation in Japan.

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, -1

The left most chip shall be output first in time. The first chip shall be aligned at the start of a transmitted symbol. The symbol duration shall be exactly 11chips long.

4.6.4 Modulation and Channel Data Rates

Two modulation formats and data rates are specified for the CFO-SS PHY: a Basic Access Rate and an Enhanced Access Rate. The Basic Access Rate shall be based on 1 Mbit/s DBPSK modulation. The DBPSK encoder is specified in Table 3. The Enhanced Access Rate shall be based on 2 Mbit/s DQPSK. The DQPSK encoder is specified in Table 4. (In the tables, +jw shall be defined as counterclockwise rotation.)
The High Speed Access Rate shall be based on CFO-SS (Carrier Frequency Offset-Spread Spectrum) scheme, which is a kind of synchronous multi-carrier DS/SS technique and utilizing a single 11 chip Barker sequence. Orthogonality among multiple carriers are achieved by separating each multiplexed carriers by 2 MHz. The CFO-SS PHY multiplexes the multiple 2 Mbit/s DQPSK signals with carrier frequencies separated by 2 MHz to enhance its access rate from 2 Mbit/s up to 10 Mbit/s. The modulation parameters of CFO-SS are summarized in Table 4.

Bit Input	Phase Change
0	0
1	π

Table 3, 2 Mbit/s DQPSK Encoding Table

Dibit pattern(d0,d1) d0 is first in time	Phase Change (+jω)
00	0
01	$\pi/2$
11	π
10	$3\pi/2$ ($-\pi/2$)

Table 4, 2 Mbit/s DQPSK Encoding Table

Modulation Scheme	Number of channels multiplexed	Modulation scheme of each channel	Total Access Rate	Channel Frequency Plan (f_1~ f_5 are relative frequencies)
1 Mbit/s CFO-SS	1	1 Mbit/s DBPSK	1x1 = 1 Mbit/s	f_1

2 Mbit/s CFO-SS	1	2 Mbit/s DQPSK	2x1 = 2 Mbit/s	f_1
4 Mbit/s CFO-SS	2	2 Mbit/s DQPSK	2x2 = 4 Mbit/s	f_1, f_2: $\lvert f_1-f_2\rvert$ = 2 MHz
6 Mbit/s CFO-SS	3	2 Mbit/s DQPSK	2x3 = 6 Mbit/s	f_1, f_2, f_3: $\lvert f_1-f_2\rvert = \lvert f_2-f_3\rvert$ = 2 MHz $\lvert f_1-f_3\rvert$ = 4 MHz
8 Mbit/s CFO-SS	4	2 Mbit/s DQPSK	2x4 = 8 Mbit/s	f_1, f_2, f_3, f_4: $\lvert f_1-f_2\rvert = \lvert f_2-f_3\rvert = \lvert f_3-f_4\rvert$ = 2 MHz $\lvert f_1-f_3\rvert = \lvert f_2-f_4\rvert$ = 4 MHz $\lvert f_1-f_4\rvert$ = 6 MHz
10 Mbit/s CFO-SS	5	2 Mbit/s DQPSK	2x5 = 10 Mbit/s	f_1, f_2, f_3, f_4, f_5: $\lvert f_1-f_2\rvert = \lvert f_2-f_3\rvert = \lvert f_3-f_4\rvert = \lvert f_4-f_5\rvert$ = 2 MHz $\lvert f_1-f_3\rvert = \lvert f_2-f_4\rvert = \lvert f_3-f_5\rvert$ = 4 MHz $\lvert f_1-f_4\rvert = \lvert f_2-f_5\rvert$ = 6 MHz $\lvert f_1-f_5\rvert$ = 8 MHz

Table 5, Modulation Parameters for CFO-SS

Notice:

For the CFO-SS system, the following conditions are mandatory to achieve the orthogonality between the multiplexed channels.

1) The symbol timing and the 11 chip Barker sequence in each channel are synchronized.
2) The 11 chip Barker sequence of all the channels are synchronized.

4.6.5 Transmit and Receive In Band and Out of Band Spurious Emissions

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

4.6.6 Transmit to Receive Turnaround Time

The TX to RX turnaround time shall be less than 10 ms including the power down ramp specified in clause 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 detection of incoming signal. The CCA should occur within 25 ms (10 ms for turnaround time plus 15 ms for energy detect) or by the next slot boundary occurring after the 25 ms has elapsed (refer to clause 4.8.4). A receiver input signal 3dB above the ED threshold described in clause 4.8.4 shall be present at the receiver.

4.6.7 Receive to Transmit Turnaround Time

The RX to TX turnaround time shall be measured at the MAC/PHY interface, using PHY_TXSTART.request and shall be less than or equal to 5 ms. This includes the transmit power up ramp described in clause 4.7.7.

4.6.8 Slot Time

The slot time for the CFO-SS PHY shall be the sum of the RX to TX turnaround time (5 ms) and the energy detect time (15 ms specified in clause 4.8.4). The propagation delay shall be regarded to be included in the energy detect time.

4.6.9 Transmit and Receive Antenna Port Impedance

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

4.6.10 Transmit and Receive Operating Temperature Range

Two temperature ranges for full operation compliance to the CFO-SS PHY are specified. Type 1 shall be defined as 0°C to 40°C is designated for office environments. Type 2 shall be defined as -30 °C to +70°C and is designated for industrial environments.

4.7 PMD Transmit Specifications

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

4.7.1 Transmit Power Levels

The maximum allowable output power as measured in accordance with practices specified by the regulatory bodies is shown in Table 6. In the USA, the radiated emissions should also conform with the ANSI uncontrolled radiation emission standards- (ANSI/IEEE C95.1-1992 or IEEE C95.1-1991).
The maximum transmission power level of each channel in the CFO-SS system is shown in Table 7.

Maximum Output Power	Geographic Location	Compliance Document
1000 mW	USA	FCC 15.247
100 mW (EIRP)	EUROPE	ETS 300-328
10 mW/MHz	JAPAN	MPT ordinance for Regulating Radio Equipment, Article49-20

Table 6, Transmit Power Levels

Modulation Scheme	Number of channels multiplexed	Relative Transmit Power per Channel
1 Mbit/s CFO-SS	1	1
2 Mbit/s CFO-SS	1	1
4 Mbit/s CFO-SS	2	1/2
6 Mbit/s CFO-SS	3	1/3
8 Mbit/s CFO-SS	4	1/4
10 Mbit/s CFO-SS	5	1/5

Table 7, Relative Transmit Power Levels for CFO-SS PHY

4.7.2 Minimum Transmitted Power Level

The minimum transmitted power shall be no less than 1 mW.

4.7.3 Transmit Power Level Control

Power control shall be provided for transmitted power greater than 100 mW. A maximum of [TBD] 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.

4.7.4 Transmit Spectrum Mask

The transmitted spectral products shall be less than -30 dBr for f_c -26 MHz < f < f_c -13 MHz and f_c +13 MHz < f < f_c + 26 MHz and -50 dBr for f < f_c -26 MHz and f > f_c + 26 MHz where f_c is the channel center frequency. The transmit spectral mask is shown in Figure 3. The measurements shall be made using 100 kHz resolution bandwidth and a 30 kHz video bandwidth.

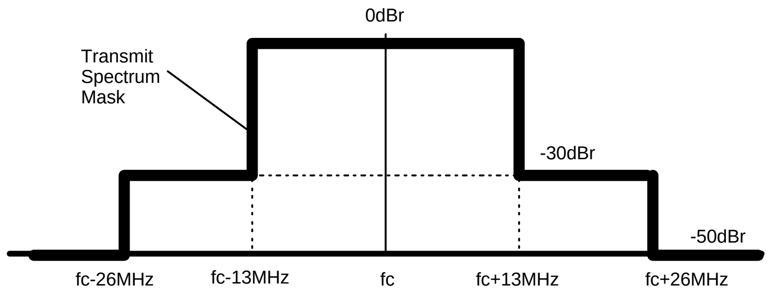

Figure 3, Transmit Spectrum Mask

4.7.5 Transmit Center Frequency Tolerance

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

4.7.6 Chip Clock Frequency Tolerance

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

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 µs.

The transmit power down ramp for 90% to 10% maximum power shall be no greater than 2 µs.

The transmit power ramps shall be constructed such that the CFO-SS PHY emissions conform with spurious frequency product specification defined in clause 4.6.5.

4.7.8 RF Carrier Suppression

The RF carrier suppression, measured at the channel center frequency, shall be at least [TBD] 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.

4.7.9 Transmit Modulation Accuracy

The transmit modulation accuracy requirement for the CFO-SS PHY shall be 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 exceeded [TBD] 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.

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 shall be corrected to compensate for the reference receiver distortion.

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

The measurement shall be made under the conditions of continuous multiplexed DQPSK signals transmission using scrambled all 1's.

The EYE pattern of the I channel shall be used to determine the I and Q sampling point. The chip clock provided by the vendor radio shall 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. This is the ideal center of the EYE and may not be the point of maximum EYE OPENING.

4.8 PMD Receiver Specifications

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

4.8.1 Receiver Minimum Input Level Sensitivity

The Frame Error Rate (FER) shall be less than [TBD] at an MPDU length of 1024 bytes for an input level of [TBD] dBm measured at the antenna connector. This FER shall be specified for the 10 Mbit/s five channel multiplexed CFO-SS signal. The test for the minimum input level sensitivity shall be conducted with the energy detection threshold set less than or equal to [TBD] dBm.

4.8.2 Receiver Maximum Input Level

The receiver shall provide a maximum FER of [TBD] at an MPDU length of 1024 bytes for a maximum input level of -4 dBm measured at the antenna. This FER shall be specified for the 10 Mbit/s five channel multiplexed CFO-SS signal.

4.8.3 Receiver Adjacent Channel Rejection

Adjacent channel rejection is defined between the two channels in each channel group defined in clause 4.6.2.

The adjacent channel rejection shall be equal to or better than 35 dB with a FER of [TBD] using 10 Mbit/s five channel multiplexed CFO-SS signal described in clause 4.6.4 and an MPDU length of 1024 bytes.

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

Input a 10 Mbit/s five channel multiplexed CFO-SS signal at a level 6 dB greater than specified in clause 4.8.1. In an adjacent channel (greater than 28 MHz separation as defined by the channel numbering), input a signal modulated in a similar fashion which adheres to the transmit mask specified in clause 4.7.4 to a level 41 dB above the level specified in clause 4.8.1. The adjacent channel signal shall 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 [TBD] .

4.8.4 Clear Channel Assessment

The CFO-SS PHY shall provide the capability to perform Clear Channel Assessment (CCA) according to at least one of the following three methods:

CCA Mode 1: Energy above threshold. CCA shall report a busy medium upon detecting any energy above the ED threshold.

CCA Mode 2: Carrier sense only. CCA shall report a busy medium only upon the detection of a CFO-SS signal. This signal may be above or below the ED threshold.

CCA Mode 3: Carrier sense with energy above threshold. CCA shall report a busy medium upon the detection of a CFO-SS signal with energy above the ED threshold.

The energy detection status shall be given by the PMD primitive, PMD_ED. The carrier sense status shall be 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-CCA.indicate.

A Busy channel shall be indicated by PHY-CCA.indicate of class BUSY.

Clear Channel shall be indicated by PHY-CCA.indicate of class IDLE.

The PHY MIB attribute aCCAModeSuprt shall indicate the appropriate operation modes. The PHY shall be configured through the PHY MIB attribute aCurrentCCAMode.

The CCA shall be TRUE if there is no energy detect or carrier sense. 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 for TX power <= 50 mW.

b) With a valid signal (according to the CCA mode of operation) present at the receiver antenna within 5 μs of the start of a MAC slot boundary, the CCA indicator shall report channel busy before the end of the slot time. This implies that the CCA signal is available as an exposed test point. Refer to Figure 47 for a definition of slot time boundary definition.

c) In the event that a correct PLCP Header is received, the CFO-SS PHY shall hold the CCA signal inactive (channel busy) for the full duration as indicated by the PLCP LENGTH field. Should a loss of carrier sense occur in the middle of reception, the CCA shall indicate a busy medium for the intended duration of the transmitted packet.

Conformance to CFO-SS PHY CCA shall be demonstrated by applying a CFO-SS compliant signal, above the appropriate ED threshold (a), such that all conditions described in (b) and (c) above are demonstrated.