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Edition 1.0 2014-03

# INTERNATIONAL STANDARD

colour inside

## Information technology – Wireless beacon-enabled energy efficient mesh network (WiBEEM) for wireless home network services –
## Part 1: PHY layer



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# INFORMATION TECHNOLOGY – WIRELESS BEACON-ENABLED ENERGY EFFICIENT MESH NETWORK (WIBEEM) FOR WIRELESS HOME NETWORK SERVICES –

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The list of all currently available parts of the ISO/IEC 29145 series, under the general title *Information technology – Wireless beacon-enabled energy efficient mesh network (WiBEEM) for wireless home network services*, can be found on the IEC web site.

This International Standard has been approved by vote of the member bodies, and the voting results may be obtained from the address given on the second title page.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

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# INTRODUCTION

This International Standard specifies the WiBEEM (Wireless Beacon-enabled Energy Efficient Mesh network) protocol, which provides low-power-consuming mesh network functions by enabling the “beacon mode operation”. WiBEEM is based on the IEEE 802.15.4 standard with additional upper layer protocols and a specific usage of the MAC layer protocol. Through the novel use of beacons, WiBEEM technology achieves longer battery life, larger network support, quicker response, enhanced mobility and dynamic reconfiguration of the network topology compared with other protocols such as ZigBee.

In the beacon mode, beacon information propagates over the entire mesh network nodes during the BOP (Beacon-Only Period) of the superframe structure without any beacon conflicts by utilising a smart beacon scheduling technique in the BOP. It also provides location information about moving devices without spending extra time running a positioning and locating algorithm by using RSSI (Received Signal Strength Indication). These features allow the WiBEEM protocol to be widely used for wireless home network services in the ubiquitous network era.

One of the key features of the WiBEEM protocol is that it has a special time interval called BOP (Beacon-Only Period) in the superframe structure that allows more than two beacons to be transmitted. This unique time period is located at the beginning of the Superframe. Because the BOP does not use the CSMA/CA mechanism, the network will not work properly in the beacon mode unless an appropriate algorithm is applied. This algorithm needs to manage and control multiple beacons in a single superframe. The solution is the Beacon Scheduling method applied in the BOP to avoid collisions among beacons, providing synchronisation among all the nodes of the entire mesh network.

For the network layer, the NAA (Next Address Available) mechanism, which is a short address allocation algorithm, has been adopted to provide an efficient way of utilising the complete 16-bit address space. The NAA algorithm does not limit the maximum number of children nodes that a node of a mesh network can have. Since the number of children nodes is unlimited, the NAA mechanism allows the WiBEEM protocol to be used not only for home network services, but also for community services. WiBEEM can be used where high network expandability through efficient use of short address spaces, device mobility and end-to-end QoS are required.

This part of ISO/IEC 29145 specifies the Physical (PHY) layer for the WiBEEM protocol.

# INFORMATION TECHNOLOGY – WIRELESS BEACON-ENABLED ENERGY EFFICIENT MESH NETWORK (WIBEEM) FOR WIRELESS HOME NETWORK SERVICES –

# Part 1: PHY layer

## 1 Scope

This part of ISO/IEC 29145 specifies the physical (PHY) layer of WiBEEM (Wireless Beacon-enabled Energy Efficient Mesh network) protocol for wireless home network services that supports a low power-consuming wireless mesh network topology as well as device mobility and QoS.

## 2 Normative reference

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 29145-2, *Information technology – Wireless beacon-enabled energy efficient mesh network (WiBEEM) for wireless home network services – Part 2: MAC layer*

## 3 Terms, definitions and abbreviations

### 3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

**3.1.1**
**access control list**
table used by a device to determine which devices are authorised to perform a specific function

**3.1.2**
**association**
service used to establish the membership of a device in a wireless mesh network

**3.1.3**
**authentication**
service used to establish the identity of one device as a member of the set of devices authorised to communicate securely to other devices in the set

**3.1.4**
**confidentiality**
assurance that communicated data remain private to the parties for whom the data are intended

**3.1.5**
**co-ordinator**
wireless device configured to provide synchronisation services through the transmission of beacons

Note 1 to entry: If a co-ordinator is the principal controller of a wireless mesh network, it is called the WMC (WiBEEM Mesh Co-ordinator).

**3.1.6**
**data integrity**
assurance that the data have not been modified from their original form

**3.1.7**
**device**
entity containing an implementation of the WiBEEM applications, NWK, MAC and physical interface to the wireless medium

**3.1.8**
**frame**
data format of aggregated bits from a medium access control (MAC) layer entity transmitted in a specified sequence

**3.1.9**
**packet**
format of aggregated bits transmitted in a specified sequence across the physical medium

**3.1.10**
**personal operating space**
space of typically about 10 m around a person or object, no matter whether this peron or object is stationary or in motion

**3.1.11**
**portable device**
device that may be moved from location to location, but uses network communications only while at a fixed location

**3.1.12**
**protocol data unit**
unit of data exchanged between two peer entities

**3.1.13**
**pseudo-random number generation**
process of generating a deterministic sequence of bits from a given seed that has the statistical properties of a random sequence of bits when the seed is not known

**3.1.14**
**service data unit**
information delivered as a unit through a service access point (SAP)

**3.1.15**
**WiBEEM end device**
WiBEEM device acting as the leaf device of a mesh network

**3.1.16**
**WiBEEM mesh co-ordinator**
WiBEEM device acting as the principal controller of a mesh network

Note 1 to entry: A WiBEEM mesh network has exactly one WiBEEM mesh co-ordinator.

**3.1.17**
**WiBEEM routable co-ordinator**
WiBEEM device acting as the router of a mesh network

**3.1.18**
**wireless medium**
medium used to implement the transfer of protocol data units (PDUs) between peer physical layer (PHY) entities of a low-rate wireless mesh network

## 3.2 Abbreviations

The following acronyms and abbreviations are used in this standard. They are commonly used in other industry publications.

| | |
|---|---|
| AES | Advanced Encryption Standard |
| BO | Beacon Order |
| BOP | Beacon Only Period |
| BOPL | Beacon Only Period Length |
| BPSK | Binary Phase-Shift Keying |
| CAP | Contention Access Period |
| CBC-MAC | Cipher Block Chaining Message Authentication Code |
| CCA | Clear Channel Assessment |
| CSMA-CA | Carrier Sense Multiple Access With Collision Avoidance |
| DSP | Deep Sleep Period |
| ED | Energy Detection |
| EIRP | Effective Isotropic Radiated Power |
| EVM | Error-Vector Magnitude |
| ID | Identifier |
| IFS | Interframe Space or Spacing |
| LLC | Logical Link Control |
| LQ | Link Quality |
| LQI | Link Quality Indication |
| LPDU | LLC Protocol Data Unit |
| LR-WPAN | Low-Rate Wireless Personal Area Network |
| LSB | Least Significant Bit |
| MAC | Medium Access Control |
| MIB | MAC Information Base |
| MLME | MAC Layer Management Entity |
| MLME-SAP | MAC Layer Management Entity-Service Access Point |
| MPDU | MAC Protocol Data Unit |
| MSB | Most Significant Bit |
| MSC | Message Sequence Chart |
| MSDU | MAC Service Data Unit |
| NAA | Next Address Available |
| NB | Number Of Backoff (periods) |
| O-QPSK | Offset Quadrature Phase-Shift Keying |
| PD-SAP | PHY Data Service Access Point |
| PDU | Protocol Data Unit |
| PER | Packet Error Rate |
| PHR | PHY Header |

| | |
|---|---|
| PHY | Physical Layer |
| PIB | PAN Information Base |
| PICS | Protocol Implementation Conformance Statement |
| PLME | Physical Layer Management Entity |
| PLME-SAP | Physical Layer Management Entity-Service Access Point |
| PN | Pseudo-Random Noise |
| POS | Personal Operating Space |
| PPDU | PHY Protocol Data Unit |
| PQP | Prioritised QoS Period |
| PSD | Power Spectral Density |
| PSDU | PHY Service Data Unit |
| QoS | Quality of Service |
| RF | Radio Frequency |
| RSSI | Received Signal Strength Indication |
| RX | Receive or Receiver |
| SAP | Service Access Point |
| SDL | Specification and Description Language |
| SDU | Service Data Unit |
| SFD | Start-of-Frame Delimiter |
| SHR | Synchronisation Header |
| TRX | Transceiver |
| TX | Transmit or Transmitter |
| WED | WiBEEM End Device |
| WiBEEM | Wireless Beacon-enabled Energy Efficient Mesh network |
| WLAN | Wireless Local Area Network |
| WM | Wireless Medium |
| WMC | WiBEEM Mesh Co-ordinator |
| WRC | WiBEEM Routable Co-ordinator |

### 3.3 Conventions

All the italicised words used in this standard shall implement all the primitives that are specified in Clause 6 and represent relevant constants defined and stored in the MIB (Management Information Base) of each layer.

## 4 Conformance

A wireless device that claims conformance to this standard shall meet all the requirements specified in 6.2, and shall implement all the primitives specified in 6.3, the PPDU formats in 6.4, the PHY Constants and the PIB attributes in 6.5, the PHY specifications in 6.6 and the general radio specifications in 6.7. Each WiBEEM device shall be able to act as a WMC, a WRC or a WED. When operating in the role of a WMC, it shall act as specified in 5.3.2, when operating in the role of a WRC, it shall act as specified in 5.3.3, and when operating in the role of a WED, it shall act as specified in 5.3.3.

# 5 Overview of the WiBEEM technology

## 5.1 General description

WiBEEM (Wireless Beacon-enabled Energy Efficient Mesh network) is a low-power-consuming wireless communication protocol that allows mesh networking capability not only in the non-beacon mode but also in the beacon mode. It is well suited for collecting sensor data in ubiquitous harsh environments. One of the most unique features of the WiBEEM protocol is that even when multiple beacons are used, the mesh network operates properly without beacon collisions by utilising a smart-beacon scheduling algorithm. Mesh networking with beacon mode is an enhancement of the non-beacon mesh network. With beacons not only can sensor nodes within the RF range communicate, but nodes that are located outside the RF range, no matter how far away, can also reliably transfer data through a multi-hop communication mechanism without requiring all the intermediate routers to be always turned on. WiBEEM protocol is a low-power consuming wireless mesh networking technology that allows wireless connectivity between devices located in ubiquitous harsh environments.

WiBEEM technology that operates in the beacon mode has several advantages. First, the power efficiency increases by controlling the synchronisation between WMC (WiBEEM Mesh Co-ordinator) and WRC (WiBEEM Routable Co-ordinator) nodes in a superframe, because all the nodes can go to DSP (Deep Sleep Period) at the same time. In other words, when the network is in idle state, all the nodes within the mesh network can enter the DSP simultaneously, and when the network is awake, the nodes can start transferring data. This synchronisation mechanism enhances power efficiency, which is one of the most critical aspects in wireless sensor networks. The second major advantage of WiBEEM protocol is that mobility is supported. Supporting mobility means that a device can be detected anywhere in the network and is able to communicate reliably, providing a flexible communications network. The WiBEEM protocol supports not only peer-to-peer or star network topologies, but also a beacon-mode mesh network structure that enhances the reliability and flexibility of the entire mesh network while lowering overall power consumption.

Some of the characteristics of WiBEEM are listed below.

– Over-the-air data rates of minimum 31,25 kbit/s and maximum 250 kbit/s.
– Mesh network as well as star and peer-to-peer operation.
– Two addressing modes are supported: 16-bit short addresses that are allocated by the mesh network; or 64-bit extended addresses.
– Beacon scheduling method for the avoidance of beacon collisions.
– Carrier sense multiple access with collision avoidance (CSMA-CA) channel access.
– Fully acknowledged protocol for transfer reliability using ARQ protocol.
– Low power consumption for not only star but also mesh topologies.
– Energy detection (ED).
– Link quality indication (LQI).
– 16 channels in the 2 450 GHz band.

Some of the advantages that WiBEEM technology has are stated below.

– It allows multiple beacons to be transmitted in a single superframe, which enables synchronisation among nodes and thus consumes very little power even in the mesh network topology.
– It supports large size network expandability without increasing transmission power or receiver sensitivity.
– It improves data communication reliability using multiple communication paths.
– The network can be easily reconfigured.
– It prolongs battery life by reducing the number of data transmission.

A system conforming to this standard consists of several components. The most basic is the device. The first device to be generated in the network is a WiBEEM mesh co-ordinator (WMC). General devices that communicate with the WMC are called WiBEEM routable co-ordinators (WRCs). Also, devices that simply transmit the sensed data are called WiBEEM end devices (WEDs). Two or more devices within a POS (Personal Operating Space) communicating on the same physical channel constitute a mesh network. However, this mesh network shall include at least one WMC, operating as the mesh co-ordinator.

## 5.2 Functions and descriptions of device types

Functions and description of WiBEEM devices are presented in ISO/IEC 29145-2.

## 5.3 Functional overview of WiBEEM

### 5.3.1 General

A wireless networking protocol is fully characterised by a superframe structure and a data transfer model between devices in the MAC layer. The WiBEEM protocol utilises the superframe structure described in 5.3.2 and data transfer model between WiBEEM devices in the MAC layer described in 5.3.3.

### 5.3.2 Superframe structure of WiBEEM

WiBEEM protocol, when it operates in the beacon mode, utilises the superframe structure in the MAC layer as shown in Figure 1. The WMC determines this superframe structure, which consists of 5 distinct time slots. The first time slot of the superframe structure is BOP (beacon only period), where only beacons of all the WRC devices can be transmitted at the times predetermined by the smart beacon scheduling algorithm without performing CSMA-CA operation. During this time period, no devices are allowed to transmit any data except the WRC that was allowed to do so. The beacon payload transmitted by the WMC device propagates over the entire mesh network and the synchronisation between all the WiBEEM devices is maintained. Right after the BOP, PQP follows in which traffic with a certain level of priority is allowed to transmit data. If the WMC device decides not to have QoS support, it can reset the PQP such that the PQP length is zero. The PQP can also be set up by the request of any WiBEEM devices when WMC is asked to do so. During the CAP the data transfer can be carried out, where back-off times are determined based on the priority that the traffic has. Any device wishing to communicate during the CAP competes with other devices using a slotted CSMA-CA mechanism. A WiBEEM device that wants to provide parameterised QoS may use RAP (reservation-based access period), where devices that acquired the permission to send data from the WMC based on the reservation request can only use this period. Optionally, the superframe can have a DSP in which all the devices enter a low-power mode.

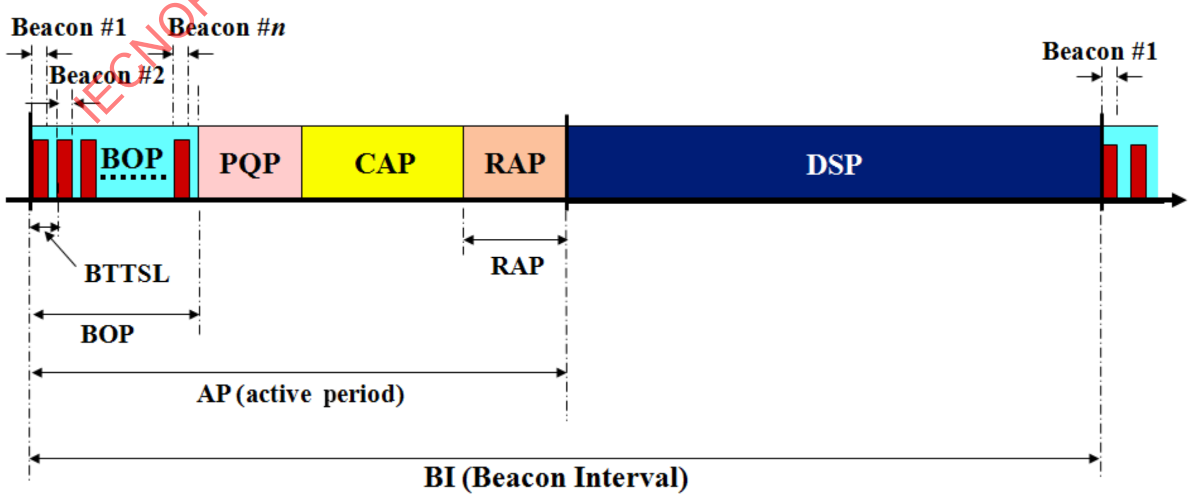


**Figure 1 – Superframe structure of WiBEEM**

### 5.3.3 Data transfer model

When a device wishes to transfer data to a co-ordinator in a beacon mode, it first listens to the network beacon. When the beacon is heard, the device synchronises to the superframe structure. At the appropriate time, the device transmits a data frame, using slotted CSMA/CA, to the co-ordinator. The co-ordinator may acknowledge the successful reception of the data by transmitting an optional acknowledgement frame. This sequence is summarised in Figure 2a. When a device wishes to transfer data in a non-beacon mode, it simply transmits a data frame, using unslotted CSMA-CA, to the co-ordinator. The co-ordinator acknowledges the successful reception of the data by transmitting an optional acknowledgement frame. The transaction is now complete. This sequence is summarised in Figure 2a. The procedure for a non-beacon mode is shown in Figure 2b.

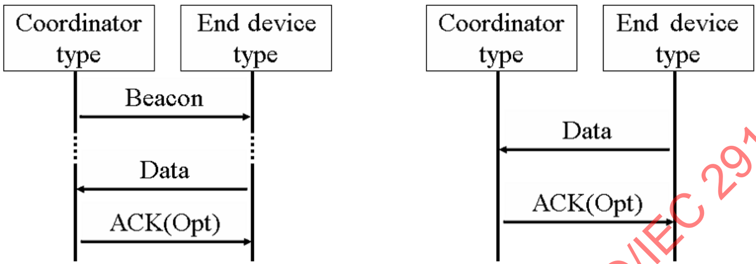


**Figure 2a – Beacon mode** **Figure 2b – Non-beacon mode**

**Figure 2 – Communication from an end device to a co-ordinator in a beacon and non-beacon mode**

When the co-ordinator wishes to transfer data to a device in a beacon mode (as shown in Figur 3a), it indicates in the network beacon that the data message is pending. The device periodically listens to the network beacon and, if a message is pending, transmits a MAC command requesting the data, using slotted CSMA-CA. WMC or WRC acknowledges the successful reception of the data request by transmitting an acknowledgement frame. The pending data frame is then sent using slotted CSMA/CA or, if possible, immediately after the acknowledgement. The device may acknowledge the successful reception of the data by transmitting an optional acknowledgement frame. The transaction is now complete. Upon successful completion of the data transaction, the message is removed from the list of pending messages in the beacon. The procedure for a non-beacon mode is shown in Figur 3b.

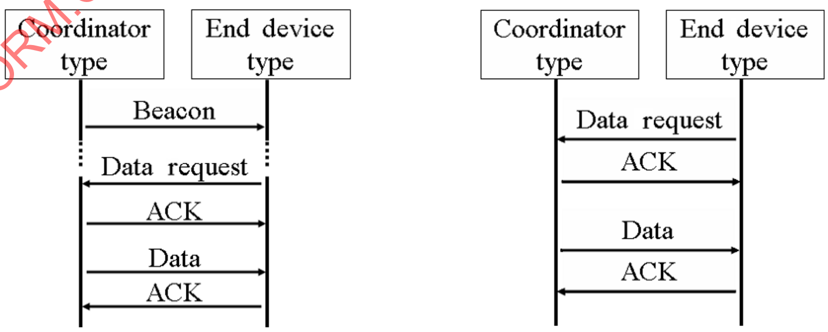


**Figure 3a – Beacon mode Beacon mode** **Figure 3b – Non-beacon mode**

**Figure 3 – Communication from a co-ordinator to an end device in a beacon and non-beacon mode**

When the co-ordinator wishes to transfer data to another co-ordinator (as shown in Figure 4), it can send data without using beacons since the co-ordinators are always active.

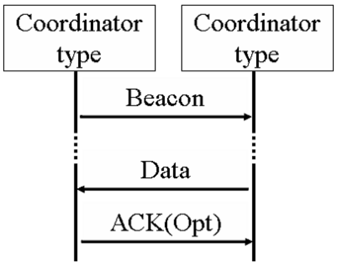


**Figure 4a – Beacon mode**

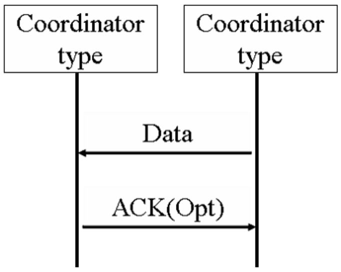


**Figure 4b – Non-beacon mode**

**Figure 4 – Communications between co-ordinators in a beacon and non-beacon mode**

End devices do not transmit beacons at any time. When an end device wishes to send data to another end device, it may communicate with other devices reachable via the build-in radio. In order to do this effectively, the devices wishing to communicate will need to either receive constantly or to synchronise with each other. In the former case, the device can simply transmit data using un-slotted CSMA-CA. In the latter case, other measures need to be taken in order to achieve synchronisation. End devices wishing to communicate shall send a frame to the target device notifying that it has data to send, and the receiver has to respond that it is ready to receive data, a shown in Figure 5. This kind of communication scheme is used in the power saving mode.

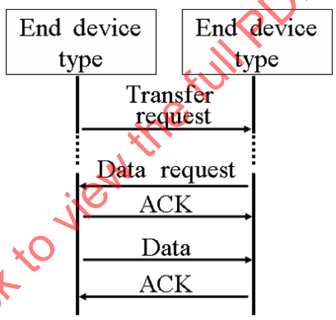


**Figure 5 – Communications between end devices**



# 6 PHY layer specifications

## 6.1 General

This clause specifies the physical layer (PHY) of the WiBEEM protocol. The PHY is responsible for the following tasks:

– activation and deactivation of the radio transceiver;
– energy detection within the current channel;
– link quality indication for received packets;
– clear channel assessment for CSMA/CA;
– channel frequency selection;
– data transmission and reception.

Constants and attributes that are specified and maintained by the PHY layer specification are written in the text of this clause in italics. Constants have a general prefix of “a”. Attributes have a general prefix of “phy”.

## 6.2 General requirements and definitions

### 6.2.1 General

This subclause specifies requirements that are common to both of the WiBEEM PHYs.

### 6.2.2 Operating frequency range

A compliant device shall operate in one or several frequency bands using the modulation and spreading formats summarised in Table 1.

NOTE The terms “chip rate” and “symbol rate” and corresponding units (chip/s and symbol/s) are used for spread spectrum code. The chip rate of a code is the number of pulses per second (chips per second) at which the code is transmitted (or received). The chip rate is larger than the symbol rate since one symbol is represented by multiple chips. The ratio is known as the spreading factor or processing gain.

**Table 1 – Frequency bands and data rate**

| PHY MHz | Frequency band MHz | Spreading parameters | | Data parameters | | |
|---|---|---|---|---|---|---|
| | | **Chip rate** kchip/s | **Modulation** | **Bit rate** kbit/s | **Symbol rate** ksymbol/s | **Symbol** |
| 868/915 | 868 to 868,6 | 300 | BPSK | 20 | 20 | Binary |
| | 902 to 928 | 600 | BPSK | 40 | 40 | Binary |
| 2 450 | 2 400 to 2 483,5 | 2 000 | O-QPSK | 31,25 | 7,812 5 | 16-ary Orthogonal |
| | | | O-QPSK | 62,50 | 15,625 | 16-ary Orthogonal |
| | | | O-QPSK | 125 | 31,25 | 16-ary Orthogonal |
| | | | O-QPSK | 250 | 62,5 | 16-ary Orthogonal |

### 6.2.3 Channel assignments and numbering

A total of 27 channels, numbered 0 to 26, are available across the three frequency bands. 16 channels are available in the 2 450 MHz band, 10 in the 915 MHz band and one in the 868 MHz band. The centre frequency ($F_c$) of these channels is defined as follows:

$$F_c = 868{,}3 \text{ in MHz, for } k = 0$$

$$F_c = 906 + 2\,(k - 1) \text{ in megahertz, for } k = 1, 2, \ldots, 10$$

and

$$F_c = 2\,405 + 5\,(k - 11) \text{ in megahertz, for } k = 11, 12, \ldots, 26$$

where $k$ is the channel number.

For each PHY supported, a compliant device shall support all channels allowed by regulations for the region in which the device operates.

### 6.2.4 RF power measurement

Unless otherwise stated, all RF power measurements that either transmit or receive, shall be carried out at the appropriate transceiver to antenna connector. The measurements shall be carried out with equipment that is either matched to the impedance of the antenna connector or corrected for any mismatch. For devices without an antenna connector, the measurements shall be interpreted as effective isotropic radiated power (EIRP) (i.e., a 0 dBi gain antenna); and any radiated measurements shall be corrected to compensate for the antenna gain in the implementation.

### 6.2.5 Transmit power

The maximum transmit power shall conform to local regulations. A compliant device shall have its nominal transmit power level indicated by its PHY parameter.

### 6.2.6 Out-of-band spurious emission

The out-of-band spurious emissions shall conform to local regulations.

### 6.2.7 Receiver sensitivity definitions

The definitions in Table 2 are referenced by subclauses elsewhere in this standard regarding receiver sensitivity.

**Table 2 – Receiver sensitivity definitions**

| Term | Definition of term | Conditions |
|---|---|---|
| Packet error rate (PER) | Average fraction of transmitted packets that are not detected correctly | – Average measured over random PSDU data |
| Receiver sensitivity | Threshold input signal power that yields a specific PER | – PSDU length = 160 octets<br>– PER < 1 %<br>– Power measured at antenna terminals<br>– Interference not present |

## 6.3 PHY service specifications

### 6.3.1 General

The PHY provides an interface between the MAC sublayer and the physical radio channel, via the RF firmware and RF hardware. The PHY conceptually includes a management entity called the PLME. This entity provides the layer management service interfaces through which layer management functions may be invoked. The PLME is also responsible for maintaining a database of managed objects pertaining to the PHY. This database is referred to as the PHY layer information base (PIB).

Figure 6 depicts the components and interfaces of the PHY.

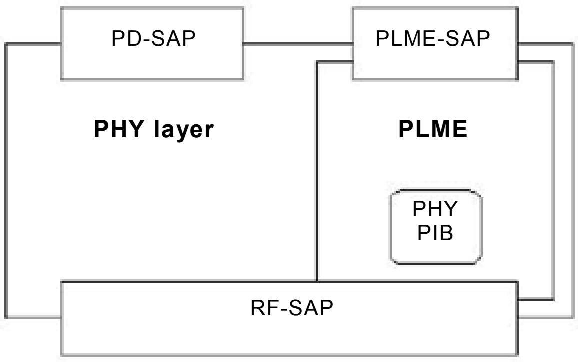


**Figure 6 – PHY reference model**

PHY provides two services, accessed through two SAPs: PHY data service, accessed through the PHY data SAP (PD-SAP), and PHY management service, accessed through the PLME's SAP (PLME-SAP).

### 6.3.2 PHY data service

#### 6.3.2.1 Overview

The PD-SAP supports the transport of MPDUs between peer MAC layer entities. Table 3 lists the primitives supported by the PD-SAP. These primitives are discussed in the subclauses referenced in Table 3.

**Table 3 – PD-SAP primitives**

| PD-SAP primitive | Request | Confirm | Indication |
|---|---|---|---|
| PD-DATA | 6.3.2.2 | 6.3.2.3 | 6.3.2.4 |



#### 6.3.2.2 PD-DATA.request

##### 6.3.2.2.1 Function

The PD-DATA.request primitive requests the transfer of an MPDU (i.e., PSDU) from the MAC sublayer to the local PHY entity.

##### 6.3.2.2.2 Semantics of the service primitive

The semantics of the PD-DATA.request primitive is as follows:

```
PD-DATA.request        (
                        psduLength,
                        psdu
                        )
```

Table 4 specifies the parameters for the PD-DATA.request primitive.

**Table 4 – PD_Data.request parameters**

| Name | Type | Valid range | Description |
|---|---|---|---|
| psduLength | Unsigned integer | ≤*aMaxPHYPacketSize* | The number of octets contained in the PSDU to be transmitted by the PHY entity |
| psdu | Set of octets | — | The set of octets forming the PSDU to be transmitted by the PHY entity. |

##### 6.3.2.2.3 When generated

The PD-DATA.request primitive is generated by a local MAC layer entity and issued to its PHY entity to request the transmission of an MPDU.

##### 6.3.2.2.4 Effect on receipt

The receipt of the PD-DATA.request primitive by the PHY entity will cause the transmission of the supplied PSDU. Provided the transmitter is enabled (TX_ON state), the PHY will first construct a PPDU, containing the supplied PSDU and then transmit the PPDU. When the PHY entity has completed the transmission, it will issue the PD-DATA.confirm primitive with a status of SUCCESS.

If the PD-DATA.request primitive is received while the receiver is enabled (RX_ON state) or if the transceiver is disabled (TRX_OFF state), the PHY entity will issue the PD-DATA.confirm primitive with a status of RX_ON or TRX_OFF, respectively.

### 6.3.2.3 PD-DATA.confirm

#### 6.3.2.3.1 Function

The PD-DATA.confirm primitive confirms the end of the transmission of an MPDU (i.e., PSDU) from a local MAC sublayer entity to a peer MAC sublayer entity.

#### 6.3.2.3.2 Semantics of the service primitive

The semantics of the PD-DATA.confirm primitive is as follows:

```
PD-DATA.confirm          (
                          Status
                          )
```

Table 5 specifies the parameters for the PD-DATA.confirm primitive.

**Table 5 – PD_DATA.confirm parameters**

| Name | Type | Valid range | Description |
|---|---|---|---|
| Status | Enumeration | SUCCESS,RX_ON, or TRX_OFF | The result of the request to transmit a packet |



#### 6.3.2.3.3 When generated

The PD-DATA.confirm primitive is generated by the PHY entity and issued to its MAC sublayer entity in response to a PD-DATA.request primitive. The PD-DATA.confirm primitive will return a status of either SUCCESS, indicating that the request to transmit was successful, or an error code of RX_ON or TRX_OFF. The reasons for these status values are fully described in 6.3.2.2.4.

#### 6.3.2.3.4 Effect on receipt

On receipt of the PD-DATA.confirm primitive, the MAC sublayer entity is notified of the result of its request to transmit. If the transmission attempt was successful, the status parameter is set to SUCCESS. Otherwise, the status parameter will indicate the error.

### 6.3.2.4 PD-DATA.indication

#### 6.3.2.4.1 Function

The PD-DATA.indication primitive indicates the transfer of an MPDU (i.e., PSDU) from the PHY to the local MAC sublayer entity.

#### 6.3.2.4.2 Semantics of the service primitive

The semantics of the PD-DATA.indication primitive is as follows:

```
PD-DATA.indication    (
                       psduLength,
                       psdu,
                       ppduLinkQuality
                       )
```

Table 6 specifies the parameters for the PD-DATA.indication primitive.

**Table 6 – PD_DATA.indication parameters**

| Name | Type | Valid range | Description |
|---|---|---|---|
| psduLength | Unsigned Integer | ≤*aMaxPHYPacketSize* | The number of octets contained in the PSDU received by the PHY entity. |
| psdu | Set of octets | — | The set of octets forming the PSDU received by the PHY entity. |
| ppduLinkQuality | Integer | 0x00 to 0xff | Link quality(LQ) value measured during reception of the PPDU (see 6.7.9). |

#### 6.3.2.4.3 When generated

The PD-DATA.indication primitive is generated by the PHY entity and issued to its MAC sublayer entity to transfer a received PSDU. This primitive will not be generated if the received psduLength field is zero or greater than *aMaxPHYPacketSize*.

#### 6.3.2.4.4 Effect on receipt

On receipt of the PD-DATA.indication primitive, the MAC sublayer is notified of the arrival of an MPDU across the PHY data service.

### 6.3.3 PHY management service

#### 6.3.3.1 Function

The PLME-SAP allows the transport of management commands between the MLME and the PLME. Table 7 lists the primitives supported by the PLME-SAP. These primitives are discussed in the clauses referenced in Table 7.

**Table 7 – PLME-SAP primitives**

| PLME-SAP Primitive | Request | Confirm |
|---|---|---|
| PLME-CCA | 6.3.3.2 | 6.3.3.3 |
| PLME-ED | 6.3.3.4 | 6.3.3.5 |
| PLME-GET | 6.3.3.6 | 6.3.3.7 |
| PLME-SET-STATE | 6.3.3.8 | 6.3.3.9 |
| PLME-SET | 6.3.3.10 | 6.3.3.11 |

#### 6.3.3.2 PLME-CCA.request

#### 6.3.3.2.1 Function

The PLME-CCA.request primitive requests that the PLME perform a CCA as defined in 6.7.10.

#### 6.3.3.2.2 Semantics of the service primitive

The semantics of the PLME-CCA.request primitive is as follows:

```
PLME-CCA.request    (
                    )
```

There are no parameters associated with the PLME-CCA.request primitive.

#### 6.3.3.2.3 When generated

The PLME-CCA.request primitive is generated by the MLME and issued to its PLME whenever the CSMACA algorithm requires an assessment of the channel.

#### 6.3.3.2.4 Effect on receipt

If the receiver is enabled on receipt of the PLME-CCA.request primitive, the PLME will cause the PHY to perform a CCA. When the PHY has completed the CCA, the PLME will issue the PLME-CCA.confirm primitive with a status of either BUSY or IDLE, depending on the result of the CCA.

If the PLME-CCA.request primitive is received while the transceiver is disabled (TRX_OFF state) or if the transmitter is enabled (TX_ON state), the PLME will issue the PLME-CCA.confirm primitive with a status of TRX_OFF or TX_ON, respectively.

### 6.3.3.3 PLME-CCA.confirm

#### 6.3.3.3.1 Function

The PLME-CCA.confirm primitive reports the results of a CCA.

#### 6.3.3.3.2 Semantics of the service primitive

The semantics of the PLME-CCA.confirm primitive is as follows:

```
PLME-CCA.confirm          (
                          status
                          )
```

Table 8 specifies the parameters for the PLME-CCA.confirm primitive.

**Table 8 – PLME-CCA confirm primitive**

| Name | Type | Valid range | Description |
|---|---|---|---|
| Status | Enumeration | TRX_OFF, TX_ON, BUSY, or IDLE | The result of the request to perform a CCA. |

#### 6.3.3.3.3 When generated

The PLME-CCA.confirm primitive is generated by the PLME and issued to its MLME in response to a PLME-CCA.request primitive. The PLME-CCA.confirm primitive will return a status of either BUSY or IDLE, indicating a successful CCA, or an error code of TRX_OFF or TX_ON. The reasons for these status values are fully described in 6.3.3.2.4.

#### 6.3.3.3.4 Effect on receipt

On receipt of the PLME-CCA.confirm primitive, the MLME is notified of the results of the CCA. If the CCA attempt was successful, the status parameter is set to either BUSY or IDLE. Otherwise, the status parameter will indicate the error.

### 6.3.3.4 PLME-ED.request

#### 6.3.3.4.1 Function

The PLME-ED.request primitive requests that the PLME perform an ED measurement (see 6.7.8).

#### 6.3.3.4.2 Semantics of the service primitive

The semantics of the PLME-ED.request primitive is as follows:

```
PLME-ED.request      (
                     )
```

There are no parameters associated with the PLME-ED.request primitive.

#### 6.3.3.4.3 When generated

The PLME-ED.request primitive is generated by the MLME and issued to its PLME to request an ED measurement.

#### 6.3.3.4.4 Effect on receipt

If the receiver is enabled on receipt of the PLME-ED.request primitive, the PLME will cause the PHY to perform an ED measurement. When the PHY has completed the ED measurement, the PLME will issue the PLME-ED.confirm primitive with a status of SUCCESS.

If the PLME-ED.request primitive is received while the transceiver is disabled (TRX_OFF state) or if the transmitter is enabled (TX_ON state), the PLME will issue the PLME-ED.confirm primitive with a status of TRX_OFF or TX_ON, respectively.



### 6.3.3.5 PLME-ED.confirm

#### 6.3.3.5.1 Function

The PLME-ED.confirm primitive reports the results of the ED measurement.

#### 6.3.3.5.2 Semantics of the service primitive

The semantics of the PLME-ED.confirm primitive is as follows:

```
PLME-ED.confirm      (
                     status,
                     EnergyLevel
                     )
```

Table 9 specifies the parameters for the PLME-ED.confirm primitive.

**Table 9 – PLME_ED.confirm parameters**

| Name | Type | Valid range | Description |
|---|---|---|---|
| Status | Enumeration | TRX_OFF, TX_ON, BUSY, or IDLE | The result of the request to perform a CCA. |
| EnergyLevel | Integer | 0x00 to 0xff | ED level for the current channel. |

#### 6.3.3.5.3 When generated

The PLME-ED.confirm primitive is generated by the PLME and issued to its MLME in response to a PLME-ED.request primitive. The PLME-ED.confirm primitive will return a status of SUCCESS, indicating a successful ED measurement, or an error code of TRX_OFF or TX_ON. The reasons for these status values are fully described in 6.3.3.4.4.

#### 6.3.3.5.4 Effect on receipt

On receipt of the PLME-ED.confirm primitive, the MLME is notified of the results of the ED measurement. If the ED measurement attempt was successful, the status parameter is set to SUCCESS. Otherwise, the status parameter will indicate the error.

### 6.3.3.6 PLME-GET.request

#### 6.3.3.6.1 Function

The PLME-GET.request primitive requests information about a given PHY PIB attribute.

#### 6.3.3.6.2 Semantics of the service primitive

The semantics of the PLME-GET.request primitive is as follows:

```
PLME-GET.request            (
                             PIBAttribute
                             )
```

Table 10 specifies the parameters for the PLME-GET.request primitive.

**Table 10 – PLME_GET.request parameters**

| Name | Type | Valid range | Description |
|---|---|---|---|
| PIBAttribute | Enumeration | See Table 21 | The identifier of the PHY attribute to get |

#### 6.3.3.6.3 When generated

The PLME-GET.request primitive is generated by the MLME and issued to its PLME to obtain information from the PHY PIB.

#### 6.3.3.6.4 Effect on receipt

On receipt of the PLME-GET.request primitive, the PLME will attempt to retrieve the requested PHY PIB attribute from its database. If the identifier of the PIB attribute is not found in the database, the PLME will issue the PLME-GET.confirm primitive with a status of UNSUPPORTED_ATTRIBUTE.

If the requested PHY PIB attribute is successfully retrieved, the PLME will issue the PLME-GET.confirm primitive with a status of SUCCESS.



### 6.3.3.7 PLME-GET.confirm

#### 6.3.3.7.1 Function

The PLME-GET.confirm primitive reports the results of an information request from the PHY PIB.

#### 6.3.3.7.2 Semantics of the service primitive

The semantics of the PLME-GET.confirm primitive is as follows:

```
PLME-GET.confirm            (
                             status,
                             PIBAttribute,
                             PIBAttributeValue
                             )
```

Table 11 specifies the parameters for the PLME-GET.confirm primitive.

**Table 11 – PLME_GET.confirm parameters**

| Name | Type | Valid range | Description |
|---|---|---|---|
| Status | Enumeration | SUCCESS or UNSUPPORTED_ATTRIBUTES | The result of the request for PHY PIB attributes information |
| PIBAttribute | Enumeration | 0x00 to 0xff | The identifier of the PHY PIB attributes to get |
| PIBAttributeValue | Various | Attribute specific | The value of the indicated OHY PIB attribute to get |



#### 6.3.3.7.3 When generated

The PLME-GET.confirm primitive is generated by the PLME and issued to its MLME in response to a PLME-GET.request primitive. The PLME-GET.confirm primitive will return a status of either SUCCESS, indicating that the request to read a PHY PIB attribute was successful, or an error code of UNSUPPORTED_ATTRIBUTE. The reasons for these status values are fully described in 6.3.3.6.4.

#### 6.3.3.7.4 Effect on receipt

On receipt of the PLME-GET.confirm primitive, the MLME is notified of the results of its request to read a PHY PIB attribute. If the request to read a PHY PIB attribute was successful, the status parameter is set to SUCCESS. Otherwise, the status parameter will indicate the error.

### 6.3.3.8 PLME-SET-TRX-STATE.request

#### 6.3.3.8.1 Function

The PLME-SET-TRX-STATE.request primitive requests that the PHY entity change the internal operating state of the transceiver. The transceiver will have three main states:

– transceiver disabled (TRX_OFF);
– transmitter enabled (TX_ON);
– receiver enabled (RX_ON).

#### 6.3.3.8.2 Semantics of the service primitive

The semantics of the PLME-SET-TRX-STATE.request primitive is as follows:

```
PLME-SET-TRX-STATE.request          (
                                     state
                                     rate
                                    )
```

Table 12 specifies the parameters for the PLME-SET-TRX-STATE.request primitive.

**Table 12 – PLME-SET-TRX-STATE.request parameters**

| Name | Type | Valid range | Description |
|---|---|---|---|
| State | Enumeration | RX_ON, TRX_OFF, FORCE_TRX_OFF, or TX_ON | The net state in which to configure the transceiver |
| Rate | Enumeration | 31.25K_ON, 62.50K_ON, 125 K_ON, | Multi-rate operation is configured |

#### 6.3.3.8.3 When generated

The PLME-SET-TRX-STATE.request primitive is generated by the MLME and issued to its PLME when the current operational state of the receiver needs to be changed.

#### 6.3.3.8.4 Effect on receipt

On receipt of the PLME-SET-TRX-STATE.request primitive, the PLME will cause the PHY to change to the requested state. If the state change is accepted, the PHY will issue the PLME-SET-TRX-STATE.confirm primitive with a status of SUCCESS. If this primitive request a state that the transceiver is already configured, the PHY will issue the PLME-SET-TRX-STATE.confirm primitive with a status indicating the current state, i.e., RX_ON, TRX_OFF, or TX_ON. If this primitive is issued with RX_ON or TRX_OFF argument and the PHY is busy transmitting a PPDU, the PHY will issue the PLME-SET-TRX-STATE.confirm primitive with a status BUSY_TX and defer the state change till the end of transmission. If this primitive is issued with TX_ON or TRX_OFF argument and the PHY is in RX_ON state and has already received a valid SFD, the PHY will issue the PLME-SET-TRX-STATE.confirm primitive with a status BUSY_RX and defer the state change till the end of reception of the PPDU. If this primitive is issued with FORCE_TRX_OFF, the PHY will cause the PHY to go the TRX_OFF state irrespective of the state the PHY is in.

The rate value of 31.25K_ON, 62.50K_ON, 125K_ON, 250K_ON denotes the multi-rate physical channel operation. By the receipt of the rate, the physical channel is now re-configured to the newly designated rate.

### 6.3.3.9 PLME-SET-TRX-STATE.confirm

#### 6.3.3.9.1 Function

The PLME-SET-TRX-STATE.confirm primitive reports the result of a request to change the internal operating state of the transceiver.

#### 6.3.3.9.2 Semantics of the service primitive

The semantics of the PLME-SET-TRX-STATE.confirm primitive is as follows:

```
PLME-SET-TRX-STATE.confirm          (
                                     status
                                     rate
                                     )
```

Table 13 specifies the parameters for the PLME-SET-TRX-STATE.confirm primitive.

**Table 13 – PLME-SET-TRX-STATE.confirm parameters**

| Name | Type | Valid range | Description |
|---|---|---|---|
| State | Enumeration | SUCCESS, RX_ON, TRX_OFF, TX_ON, BUSY_RX, or BUSY_TX | The result of the request to change the state of the transceiver. |
| Rate | Enumeration | 31.25K_ON, 62.50K_ON, 125K_ON, 250K_ON | Multi-rate operation is confirmed |

#### 6.3.3.9.3 When generated

The PLME-SET-TRX-STATE.confirm primitive is generated by the PLME and issued to its MLME after attempting to change the internal operating state of the transceiver.

#### 6.3.3.9.4 Effect on receipt

On receipt of the PLME-SET-TRX-STATE.confirm primitive, the MLME is notified of the result of its request to change the internal operating state of the transceiver. A status value of SUCCESS indicates that the internal operating state of the transceiver was accepted. A status value of RX_ON, TRX_OFF, or TX_ON indicates that the transceiver is already in the requested internal operating state. A status value of BUSY_TX is issued when the PHY is requested to change its state to RX_ON or TRX_OFF while transmitting. A status value of BUSY_RX is issued when the PHY is in RX_ON state, has already received a valid SFD and is requested to change its state to TX_ON or TRX_OFF.

Also, the MLME is notified the newly configured rate value by the primitive.

### 6.3.3.10 PLME-SET.request

#### 6.3.3.10.1 Function

The PLME-SET.request primitive attempts to set the indicated PHY PIB attribute to the given value.

#### 6.3.3.10.2 Semantics of the service primitive

The semantics of the PLME-SET.request primitive is as follows:

```
PLME-SET.request                (
                                PIBAttribute,
                                PIBAttributeValue
                                )
```

Table 14 specifies the parameters for the PLME-SET.request primitive.

**Table 14 – PLME_SET.request parameters**

| Name | Type | Valid range | Description |
|---|---|---|---|
| PIBAttribute | Enumeration | RX_ON, TRX_OFF, FORCE_TRX_OFF, or TX_ON | The identifier of the PIB attribute to set. |
| PIBAttributeValue | Various | Attribute specific | The value of the indicated PIB attribute to set |

#### 6.3.3.10.3 When generated

The PLME-SET.request primitive is generated by the MLME and issued to its PLME to write the indicated PHY PIB attribute.

#### 6.3.3.10.4 Effect on receipt

On receipt of the PLME-SET.request primitive, the PLME will attempt to write the given value to the indicated PHY PIB attribute in its database. If the PIBAttribute parameter specifies an attribute that is not found in the database (see Table 21), the PLME will issue the PLME-SET.confirm primitive with a status of UNSUPPORTED_ATTRIBUTE. If the PIBAttibuteValue parameter specifies a value that is out of the valid range for the given attribute, the PLME will issue the PLME-SET.confirm primitive with a status of INVALID_PARAMETER.

If the requested PHY PIB attribute is successfully written, the PLME will issue the PLME-SET.confirm primitive with a status of SUCCESS.

### 6.3.3.11 PLME-SET.confirm

#### 6.3.3.11.1 Function

The PLME-SET.confirm primitive reports the results of the attempt to set a PIB attribute.

#### 6.3.3.11.2 Semantics of the service primitive

The semantics of the PLME-SET.confirm primitive is as follows:

```
PLME-SET.confirm                    (
                                     status,
                                     PIBAttribute
                                     )
```

Table 15 specifies the parameters for the PLME-SET.confirm primitive.

**Table 15 – PLME_SET.confirm parameters**

| Name | Type | Valid range | Description |
|---|---|---|---|
| Status | Enumeration | SUCCESS, UNSUPPORTED_ATTRIBUTE,<br>Or INVALID_PARAMETER | The status of the attempt to set the request PIB attribute |
| PIBAttribute | Enumeration | See Table 21 | The identifier of the PIB attribute being confirmed |

#### 6.3.3.11.3 When generated

The PLME-SET.confirm primitive is generated by the PLME and issued to its MLME in response to a PLME-SET.request primitive. The PLME-SET.confirm primitive will return a status of either SUCCESS, indicating that the requested value was written to the indicated PHY PIB attribute, or an error code of UNSUPPORTED_ATTRIBUTE or INVALID_PARAMETER. The reasons for these status values are fully described in 6.3.3.10.4.

#### 6.3.3.11.4 Effect on receipt

On receipt of the PLME-SET.confirm primitive, the MLME is notified of the result of its request to set the value of a PHY PIB attribute. If the requested value was written to the indicated PHY PIB attribute, the status parameter is set to SUCCESS. Otherwise, the status parameter will indicate the error.

### 6.3.4 PHY enumerations description

Table 16 shows a description of the PHY enumeration values defined in the PHY specification.

**Table 16 – PHY enumerations description**

| Enumeration | Value | Description |
|---|---|---|
| BUSY | 0x00 | The CCA attempt has detected a busy channel. |
| BUSY_RX | 0x01 | The transceiver is asked to change its state while receiving. |
| BUSY_TX | 0x02 | The transceiver is asked to change its state while transmitting. |
| FORCE_TRX_OFF | 0x03 | The transceiver is to be switched off. |
| IDLE | 0x04 | The CCA attempt has detected an idle channel. |
| INVALID_PARAMETER | 0x05 | A SET/GET request was issued with a parameter in the primitive that is out of the valid range. |
| RX_ON | 0x06 | The transceiver is in or is to be configured into the receiver enabled state. |
| SUCCESS | 0x07 | A SET/GET, an ED operation, or a transceiver state change was successful. |
| TRX_OFF | 0x08 | The transceiver is in or is to be configured into the transceiver disabled state. |
| TX_ON | 0x09 | The transceiver is in or is to be configured into the transmitter enabled state. |
| UNSUPPORTED_ATTRIBUTE | 0x0a | A SET/GET request was issued with the identifier of an attribute that is not supported. |

## 6.4 PPDU format

### 6.4.1 Function

This subclause specifies the format of the PPDU packet.

For convenience, the PPDU packet structure is presented so that the leftmost field as written in this standard shall be transmitted or received first. All multiple octet fields shall be transmitted or received least significant octet first and each octet shall be transmitted or received least significant bit (LSB) first. The same transmission order should apply to data fields transferred between the PHY and MAC sublayer.

Each PPDU packet consists of the following basic components:

– -SHR, which allows a receiving device to synchronise and lock onto the bit stream;

– -PHR, which contains frame length information;

– -variable length payload, which carries the MAC sub-layer frame.

### 6.4.2 General packet format

#### 6.4.2.1 General

The PPDU packet structure shall be formatted as illustrated in Table 17.

**Table 17 – Format of the PDU**

<table>
<tr><th>Octets: 4</th><th>1</th><th colspan="2">1</th><th>Variable</th></tr>
<tr><td>Preamble</td><td>SFD</td><td>Frame length</td><td>Reserved</td><td>PSDU</td></tr>
<tr><td colspan="2">SHR</td><td colspan="2">PHR</td><td>PHY payload</td></tr>
</table>

#### 6.4.2.2 Preamble field

The preamble field is used by the transceiver to obtain chip and symbol synchronisation with an incoming message. The preamble field shall be composed of 32 binary zeros.

#### 6.4.2.3 SFD field

The SFD is an 8 bit field indicating the end of the synchronisation (preamble) field and the start of the packet data. The basic format of 250 kbit/s is shown Table 18.

**Table 18 – Format of the SFD field**

| Bits:0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 |



However, if an adaptation is made to the SFD field, it can also be used for signalling of the different channel speeds. The problem arises when noticing that the SFD field shall be transmitted with the spreading sequence of the 250 kbit/s mode transmitted only once, which, of course, has a lower performance than the multi-repetition 125 kbit/s, 62,5 kbit/s and 31,25 kbit/s modes.

In order to tackle this problem, two different methods can be applied.

– For the lowest bit rate modes (125 kbit/s, 62,5 kbit/s and 31,25 kbit/s), the SFD field is transmitted two, four or eight times, respectively. This requires a change in the detector, because different detectors have to be involved in order to obtain the correct mode.
– For all modes, the SFD length remains constant. By permutation of all possible combinations of SFD fields, the best performing set is chosen and used for signalling.

#### 6.4.2.4 Frame length field

The frame length field is 7 bit in length and specifies the total number of octets contained in the PSDU (i.e., PHY payload). It is a value between 0 and *aMaxPHYPacketSize* (see 6.3.2.2.2). Table 19 summarises the type of payload versus the frame length value.

**Table 19 – Frame length values**

| Frame length value | Payload |
|---|---|
| *0 to 4* | Reserved |
| *5* | MPDU(Acknowledgement) |
| *6 to 7* | Reserved |
| *8 to aMaxPHYPacketSize* | MPDU |

#### 6.4.2.5 PSDU field

The PSDU field has a variable length and carries the data of the PHY packet. For all packet types of length five octets or greater than seven octets, the PSDU contains the MAC sublayer frame (i.e., MPDU).

### 6.5 PHY constants and PIB attributes

#### 6.5.1 Function

This subclause specifies the constants and attributes required by the PHY.

### 6.5.2 PHY constants

The constants that define the characteristics of the PHY are presented in Table 20. These constants are hardware dependent and cannot be changed during operation.

**Table 20 – PHY constants**

| Constant | Description | Value |
|---|---|---|
| *aMaxPHYPacketSize* | The maximum PSDU size(in octets) the PHY shall be able to receive. | 127 |
| *aTurnaroundTime* | RX-to-TX or TX-to-RX maximum turnaround time (see 6.7.2 and 6.7.3) | 12 symbol periods |

### 6.5.3 PHY PIB attributes

The PHY PIB comprises the attributes required to manage the PHY of a device. Each of these attributes can be read or written using the PLME-GET.request and PLME-SET.request primitives, respectively. The attributes contained in the PHY PIB are presented in Table 21.

**Table 21 – PHY PIB attributes**

| Attribute | Identifier | Type | Range | Description |
|---|---|---|---|---|
| phyCurrentChannel | 0x00 | Integer | 0 to 26 | The RF channel to use for all following transmissions and receptions (see 6.2.3) |
| phyChannelsSupported | 0x01 | Bitmap | See description | The 5 most significant bits (MSBs)($b_{27}$,..,$b_{37}$) of phyChannlesSupported shall be reserved and set to 0, and the 27 LSBs($b_0$,$b_1$,...$b_{26}$) shall indicate the status (1 = available,0 = unavailable) for each of the 27 valid channels(b shall indicate the status of channel $k$ as in 6.2.3). |
| phyTranmitPower | 0x02 | Bitmap | 0x00 to 0xbf | The 2 MSBs represent the tolerance on the transmit power<br>00 = ±1 dB<br>01 = ±3 dB<br>10 = ±6 dB<br>The 6 LSBs represent a signed integer in two's complement format, corresponding to the nominal transmit power of the device in decibels relative to 1 mW. The lowest value of phyTransmitPower shall be interpreted as less than or equal to −32 dBm |
| PhyCCAMode | 0x03 | Integer | 1 to 3 | The CCA mode (see 6.7.10). |



## 6.6 2 450 MHz PHY specifications

### 6.6.1 Requirements

The requirements for the 2 450 MHz PHY are specified in 6.6.2 through 6.6.3.

### 6.6.2 Data rate

The data rate of the WiBEEM (2 450 MHz) PHY shall be 31,25 kbit/s, 62,5 kbit/s, 125 kbit/s or 250 kbit/s.

### 6.6.3 Modulation and spreading

#### 6.6.3.1 Overview

The 2 450 MHz PHY employs a 16-ary quasi-orthogonal modulation technique on the 31,25 kbit/s ~ 250 kbit/s. During each data symbol period, four information bits are used to select one of 16 nearly orthogonal pseudo-random noise (PN) sequences to be transmitted. The PN sequences for successive data symbols are concatenated, and the aggregate chip sequence is modulated onto the carrier using offset quadrature phase-shift keying (O-QPSK).

#### 6.6.3.2 Reference modulator diagram

The functional block diagram in Figure 7 is provided as a reference for specifying the 2 450 MHz PHY modulation and spreading functions (for 31,25 kbit/s ~ 500 kbit/s). The number in each block refers to the subclause that describes that function.

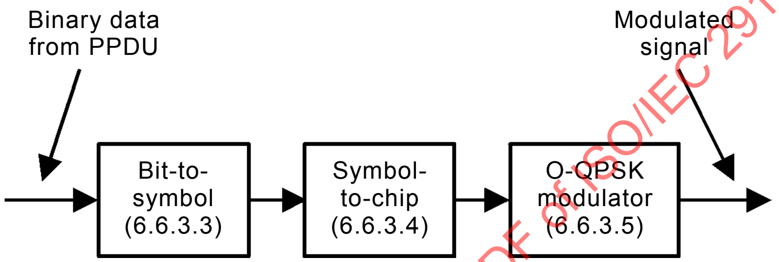


**Figure 7 – Modulation and spreading functions**

#### 6.6.3.3 Bit-to-symbol mapping

For 31,25 kbit/s to 250 kbit/s, all binary data contained the PPDU shall be encoded using the modulation and spreading functions shown in Figure 7. This subclause describes how binary information is mapped into data symbols.

The 4 LSBs ($b_0$, $b_1$, $b_2$, $b_3$) of each octet shall map into one data symbol, and the 4 MSBs ($b_4$, $b_5$, $b_6$, $b_7$) of each octet shall map into the next data symbol. Each octet of the PPDU is processed through the modulation and spreading functions sequentially, beginning with the preamble field and ending with the last octet of the PSDU. Within each octet, the least significant symbol ($b_0$, $b_1$, $b_2$, $b_3$) is processed first and the most significant symbol ($b_4$, $b_5$, $b_6$, $b_7$) is processed second.

#### 6.6.3.4 Symbol-to-chip mapping

Each data symbol shall be mapped into a 32-chip PN sequence.

For 250 kbit/s, the symbol-to-chip mapping sequence is shown in Figure 8.