78. Energy-Efficient Ethernet (EEE)

78.1.4 PHY types optionally supporting EEE

Insert new row below into Table 78-1 after 1000BASE-KX:

Table 78–1—Clauses associated with each PHY or interface type

PHY or interface type	Clause
1000BASE-RH	114, 115

78.2 LPI mode timing parameters descriptions

Insert new 1000BASE-RH row above into Table 78-2 after 1000BASE-KX:

Table 78–2—Summary of the key EEE parameters for supported PHYs or interfaces

PHY Type	T_s (μs)		T_q (μs)		T_r (μs)	
	Min	Max	Min	Max	Min	Max
1000BASE-RH	0	0	23.~~83~~52	23.~~83~~52	~~0~~1.~~985~~30	~~0~~1.~~985~~30

78.5 Communication link access latency

Insert new 1000BASE-RH row below into Table 78-4 after 1000BASE-KX:

Table 78–4—Summary of the LPI timing parameters for supported PHYs or interfaces

PHY Type	Case	$T_{w\_sys\_tx}$ (min) (μs)	T_{w_phy} (min) (μs)	$T_{phy\_shrink\_tx}$ (min) (μs)	$T_{phy\_shrink\_rx}$ (min) (μs)	$T_{w\_sys\_rx}$ (min) (μs)
1000BASE-RH		24.~~82~~88	24.~~82~~88	24.~~82~~88	0	0

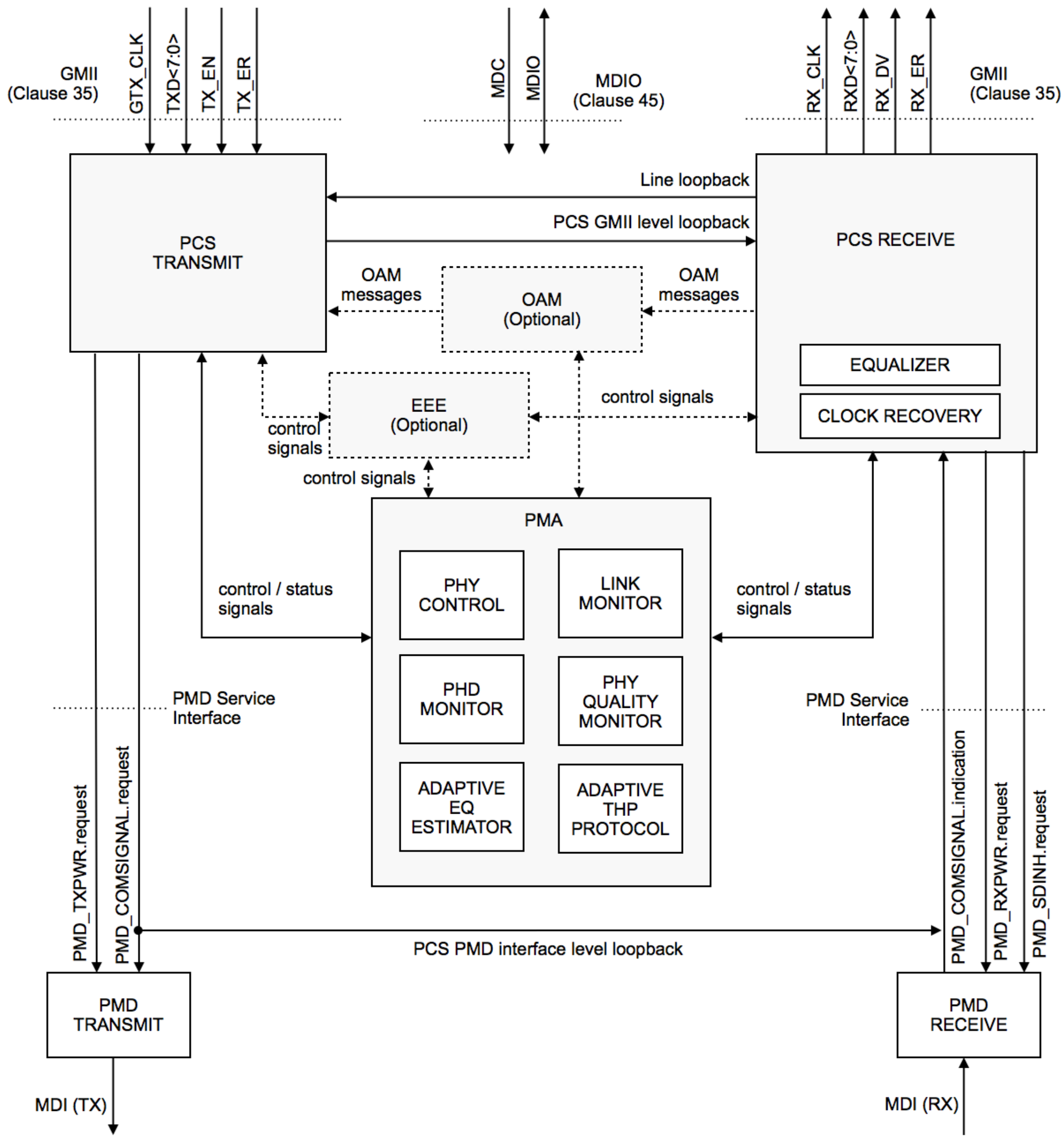

Figure 114–6—Functional block diagram

114.2 Physical Coding Sublayer

The 1000BASE-H PCS couples a Gigabit Media Independent Interface (GMII), see Clause 35, to the Physical Medium Dependent (PMD) sublayer. ~~The transmitters performed by the PCS include encoding the GMII transmit data stream, encapsulation of coded data into Transmit Blocks, and mapping Transmit Blocks into PAM symbols using the Multi-Level Coset Coding technique (MLCC). The receive functions performed by the PCS comprise mapping received MLCC coded PAM symbols into received Transmit Blocks, and decoding the data into a receive GMII data stream.~~

and field RXO_TYPE of ~~the OAM_DATA1 through OAM_DATA8 receive registers~~register 3.509.
Values: Any value

txphd_phyt
Value of the PHD field PHD.OAM.PHYT being transmitted by the local PHY. It indicates to the remote PHY the ~~PHD.OAM.MSGT~~ toggle bit identifier of the last valid message written to the ~~Rx~~ receive registers.
Values: It alternates between values 0 and 1

txphd_mert
Content of the PHD field PHD.OAM.MERT being transmitted by the local PHY. It informs the remote PHY ~~which is~~ the toggle bit identifier of the last message that has been received by the local ~~ME~~Management Entity.
Values: It alternates between values 0 and 1

rxphd_msgt
Value of the PHD field PHD.OAM.MSGT of the last valid received PHD. It contains the toggle bit identifier of the OAM message carried in that PHD.
Values: It alternates between values 0 and 1

rxphd_oamudat
Content of fields PHD.OAM.~~HDR~~ TYPE and PHD.OAM.DATAx of the last PHD correctly received by the local PHY. It is the payload of the OAM message.
Values: Any value

read_RXOAM_CTRL_event
Event to indicate that the OAM receive register ~~RXOAM_CTRL~~ 3.509 has been read.
Values: TRUE: register ~~RXOAM_CTRL~~ 3.509 has been read
FALSE: register ~~RXOAM_CTRL~~ 3.509 has not been read

read_RXOAM_DATA8_event
Event to indicate that the OAM receive register ~~OAM_DATA8~~ 3.517 has been read.
Values: TRUE: register ~~RXOAM_DATA8~~ 3.517 has been read
FALSE: register ~~RXOAM_DATA8~~ 3.517 has not been read

114.5 Energy Efficient Ethernet (EEE)

Each PHY ~~that supports EEE~~ shall advertise its EEE capability ~~when it is connected~~ to ~~a~~ the link ~~by setting~~ partner in the ~~1-bit~~ field PHD.CAP.LPI ~~of the Physical Header Data~~ as one (~~PHD~~see Table 114–2) ~~to 1,~~ when the local PHY implements EEE and it is enabled (see ~~Table 114–3~~45.2.3.50.4). EEE functionality shall be enabled when both link partners indicate PHD.CAP.LPI = 1. PHD.CAP.LPI = 1 advertisement indicates to the link partner that the local PHY can generate Transmit Blocks according to LPI mode of operation and it is able to accept Transmit Blocks from the link partner that conform to LPI operation~~.~~ .

If the link partner PHY does not advertise EEE capability (PHD.CAP.LPI = 0), then the link will always operate in normal mode in both transmit and receive directions even if “Assert LPI” encoding is detected on the GMII. Therefore, when two link partners do not agree on enabling LPI capability, the PCS encoding will be transparent ~~allowing~~ carrying the LPI signaling GMII to GMII, but the PHY will not enter quiet mode.

As shown in ~~Figure 114–87~~Figure 114–86, 1000BASE-H LPI mode consists of alternating refresh and quiet periods. Refresh is provided by transmitting all the pilot and physical header sub-blocks; and quiet is provided by suspending transmission of the payload data sub-blocks. In quiet periods, the local PHY may turn off much of the PCS, PMA and PMD transmitter. No ~~(or minimal)~~ optical power is injected into the fiber during these periods of quiet resulting in reduced power consumption. Quiet shall not be entered or exited in the middle of a payload data sub-block~~.~~ .

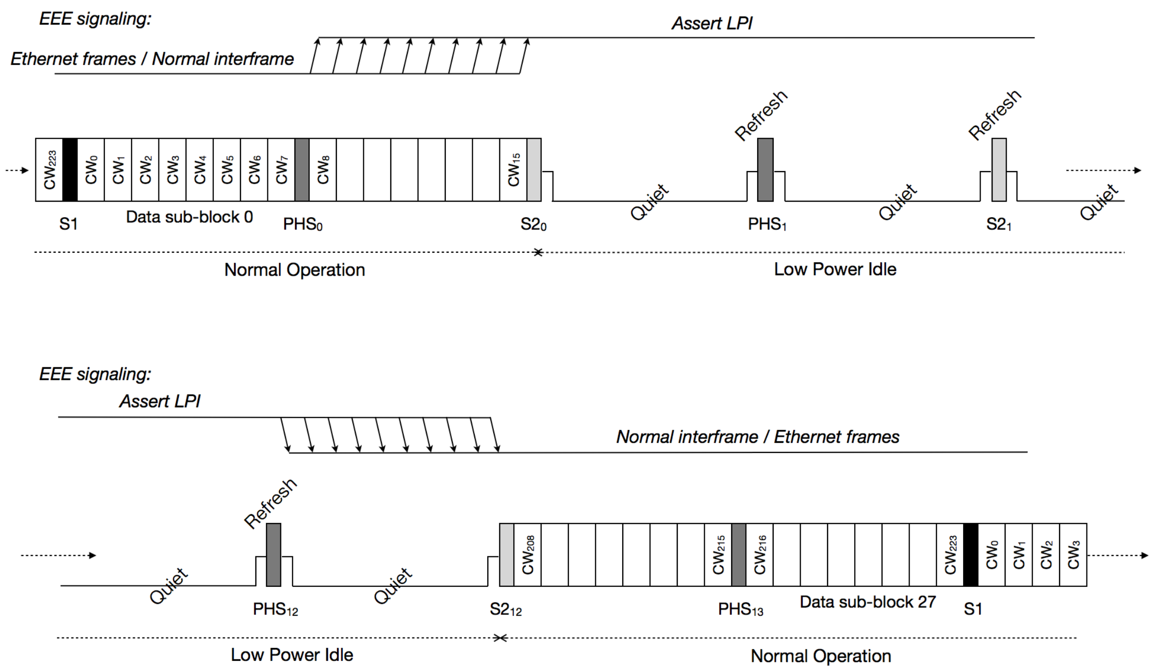

Figure 114–86— 1000BASE-H LPI operation

Pilot and physical header sub-blocks serve as refresh signals at the receiver to update adaptive filters and timing circuits in order to maintain link integrity. These sub-blocks are generated as in normal mode. Each sub-block is composed of 128 modulation symbols plus the 16 zero symbol prefix and postfix sequences (see 114.2.1).

The PHY receiver shall detect if its link partner is operating in LPI mode based on the received signal at the beginning of each payload data sub-block. The PHY transmitter shall indicate to its link partner it is entering a quiet period by the transmission of ~~96~~ 146 contiguous zero value symbols. ~~(~~The normal 16 zeroes post-fixed to the pilot or physical header sub-block ~~plus 80~~ are appended by 130 additional ~~zeroes).~~ zeroes intended to be used by the remote PHY receiver for detection of the quiet period and also by the PMD receive function to save the state of circuitry and switch off the opto-electrical signal translation before the optical power is switched off by the transmitter.The transmitter shall then enter its quiet state until ~~80~~ 130 symbol times before the end of the payload data sub-block period. ~~The~~ After this, the transmitter shall insert ~~80~~ 130 zero value symbols before the transmission of the ~~corresponding pilot or physical header sub-block~~

~~(including its 16 prefixed zeroes)~~ refresh signals to prepare the link partner for ~~reception of refresh signals.~~ reception.

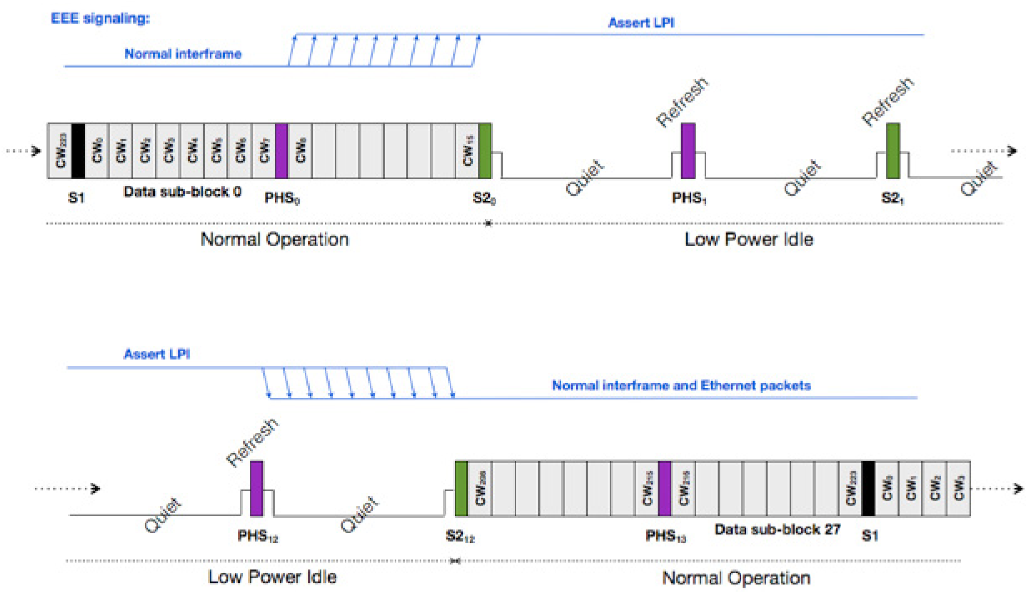

Figure 114–87—1000BASE-H PHY LPI mode

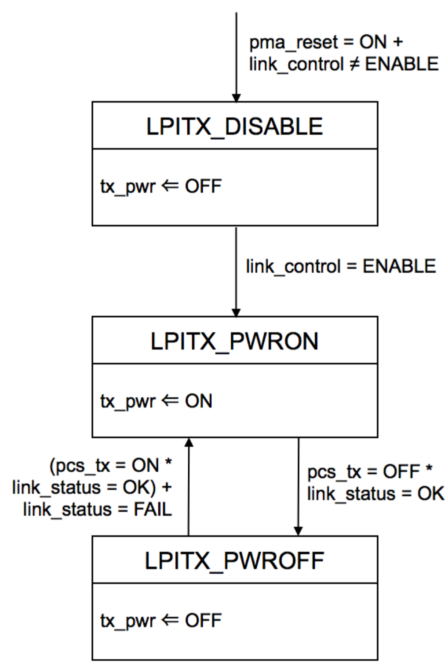

Figure 114–88—1000BASE-H LPI PMD TX control state diagram

Control signaling is used to support EEE reduced power consumption. Any 1000BASE-H PMD supporting optional EEE shall provide the functionality represented by the following PMD service interface primitives:

— PMD_TXPWR.request(tx_pwr): this primitive is generated by the PCS transmitter to request either switching off the ~~minimum PMD~~ optical output power ~~compatible with~~ during quiet periods in LPI mode, or switching on the optical power for refresh signals transmission in LPI mode or for normal operation.

— PMD_RXPWR.request(rx_pwr): this primitive is generated by the PCS receiver to cause the PMD receive function to transition between being able to respond to received optical signals and a minimum power consumption ~~state compatible with LPI mode~~state. In response to this request, the PMD receive function saves the internal state of the circuitry during link partner transmitted quiet periods allowing resumption of reception in a very short period of time.

— PMD_SDINH.request(sd_inh): this primitive is generated by the PCS receiver to inhibit the PMD signal detect function when the link has been established, taking the PCS receiver the responsibility to determine the quality of the signal and avoiding incorrect operation of PMD signal detect function when PHY receiver is operating in LPI mode.

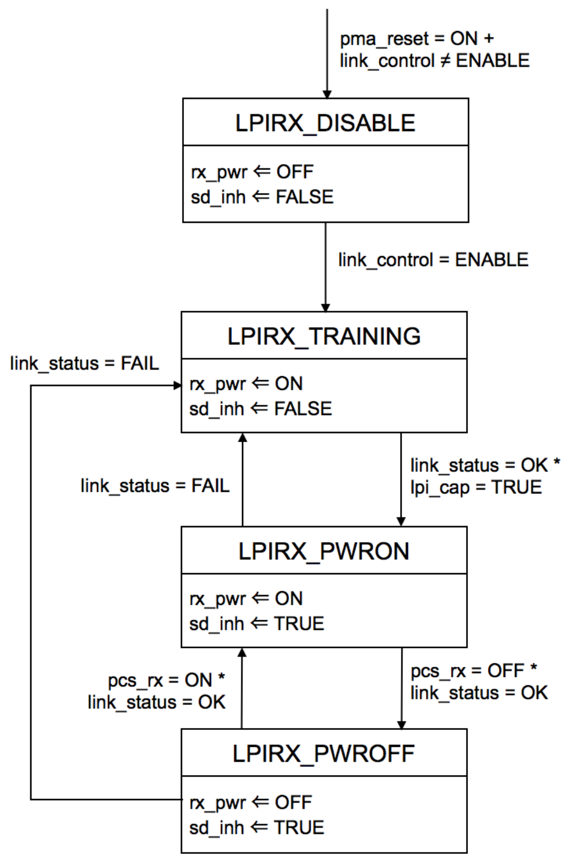

Figure 114–89—1000BASE-H LPI PMD RX control state diagram

~~Figure 114–90~~Figure 114–88 and ~~Figure 114–91~~Figure 114–89 show the state diagrams that govern the generation of ~~tx_pwr~~ tx_pwr, rx_pwr and ~~rx_pwr signals, respectively,~~ sd_inh signals for control of the

PMD. All the variables used in these state diagrams that have not been previously introduced are defined in 114.5.1~~. .~~.

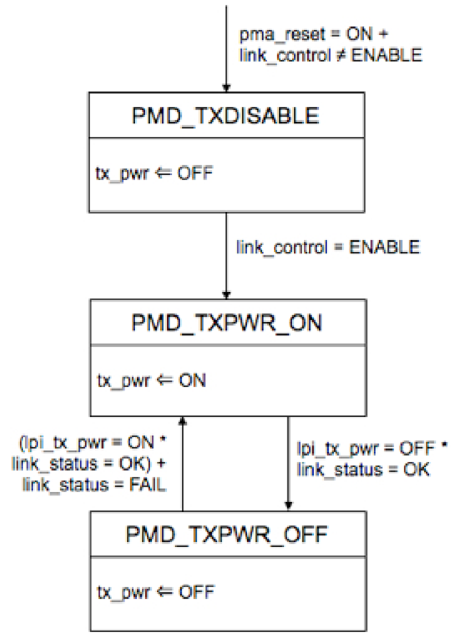

Figure 114–90—1000BASE-H PMD TX control state diagram

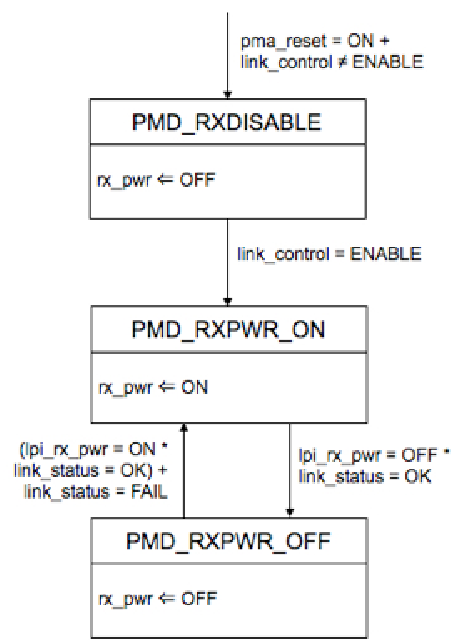

Figure 114–91—1000BASE-H PMD RX control state diagram

114.5.1 PMD control state variables

lpi_cap
: Controls the enable of LPI functionality. This variable is set to TRUE when PHD.CAP.LPI of both transmit and receive PHD is TRUE. Otherwise it is FALSE.
: Values: TRUE: both local and remote PHY have EEE ability and EEE functionality is enabled in both PHYs
  FALSE: either local or remote PHY do not have EEE ability or it is disabled

tx_pwr
: Indicates to the PMD transmitter ~~is~~ to generate, or not, signal at the MDI.
: Values: ON: the PMD generates signal at the MDI.
  OFF: the PMD ~~will~~ does not generate signal at the MDI, and may reduce ~~power~~ power consumption.

~~tx_pwr~~rx_pwr
: Indicates to the PMD ~~transmitter is~~ receive function to ~~generate~~ignore, or not, signal at the MDI.
: Values: ON: the PMD ~~generates~~ receive function receives signal at MDI and transfer to the ~~MDI~~PCS receiver.
  OFF: the PMD ~~will not generate~~ receive function ignores signal at the MDI, saves the internal state of the circuitry, and may reduce power consumption.

~~rx_pwr~~sd_inh
: Indicates to the PMD ~~receive~~ signal detect function to ~~ignore~~be, or not, ~~signal at the MDI~~inhibited.
: Values: ~~ON~~TRUE: the PMD ~~receive~~ signal detect function ~~receives signal at MDI for transfer to the PCS~~is inhibited ~~receive function.~~
  ~~OFF~~FALSE: the PMD ~~receive~~ signal detect function ~~ignores signal at the MDI, saves the internal state of the circuitry, and may reduce power consumption.~~operates normally

~~lpi_tx_pwr~~pcs_tx
: Signal internally generated by the PCS transmitter during LPI operation
: Values: ON: enable ~~PMD~~ PCS transmit (refresh).
  OFF: disable ~~PMD~~ PCS transmit (quiet).

~~lpi_rx_pwr~~pcs_rx
: Signal internally generated by PCS ~~receive function~~ receiver during LPI operation
: Values: ON: enable ~~PMD~~ PCS receive (refresh).
  OFF: disable ~~PMD~~ PCS receive (quiet)~~.~~

114.5.2 1000BASE-H PHY LPI mode transmit operation

When “Assert LPI” is signaled on the GMII , the transmitter of the local PCS encodes the “Assert LPI” signal on the PDBs as defined in Table 114–1.

Once a PDB that contains an “Assert LPI” has been completely transmitted to its link partner, the local PHY transmitter enters quiet at the beginning of the next payload data ~~payload~~ sub-block unless the GMII signals normal-interframe before the end of the current payload data ~~payload~~ sub-block.

The transmitter of the local PHY is enabled periodically to transmit pilot and physical header sub-blocks (refresh signals) at the same time as they would be transmitted in normal operating mode.

During LPI operation, the transmitter replaces any payload data ~~payload~~ sub-block with:

- transmission of ~~80~~ 130 zero symbols, to indicate entry to quiet;
- ~~minimum PMD~~ no output optical ~~output~~ power ~~compatible with LPI mode~~ during ~~7744~~ 7644 symbols (quiet);
- transmission of ~~80~~ 130 zero symbols, to prepare the reception of pilot and physical header sub-blocks used as refresh signals

This quiet-refresh cycle continues until the reception of the normal-interframe encoding on the GMII. ~~-~~The local PHY transmitter then exits LPI mode and resumes normal operation at the beginning of the next payload data sub-block.

The 64B/65B PCS encoder shall preserve timing during quiet mode. Therefore, the time alignment of transmitted PDBs ~~in relationship~~ relative to FEC codewords ~~shall be exactly the same~~ when the PHY re-enters ~~the~~ normal operation ~~that would~~ shall be ~~if~~ exactly the ~~PHY had not entered~~ same as it would have been in the absence of an LPI ~~quiet mode~~interval. This preserves the PCS decoder synchronization of the link partner and coherence with information encoded in the field PHD.TX.NEXT.PDB.OFFSET of the last received PHD.

Unlike some other EEE PHYs, neither sleep nor wake specific signals are used to enter and leave the LPI mode of operation. Instead, sleep is indicated to the link partner by the transmission of ~~80~~ 130 zero symbols that replace the beginning of a payload data sub-block. Wake is implicit in the presence of normal ~~16-PAM~~ PAM16 Tomlinson-Harashima precoded signal at the beginning of a payload data sub-block~~-~~.

114.5.3 1000BASE-~~RH~~ H PHY LPI mode receive operation

In the receive direction, entering LPI mode is triggered by the detection of a sequence of zero symbols instead of ~~PAM/~~PAM16-THP signal at the beginning of a data sub-block. When the local PHY receiver detects this event, it encodes “Assert LPI” on the GMII and disables some functionality to reduce power consumption.

NOTE -- “Assert LPI” can also be encoded on the GMII ~~RX~~ receive stream due to the reception of PDBs containing LPI signaling from the link partner (this is the case of LPI assertion on the GMII ~~TX~~ transmit stream in the middle of a payload data sub-block transmission).

In LPI mode, the local PHY receiver shall use received pilot and physical header sub-blocks, which are sent periodically by the link partner, to update adaptive coefficients and timing circuits and to determine the value of loc_rcvr_status. Therefore, in LPI mode, the receiver shall also use the refresh signals to estimate the quality of decoding (i.e. link margin).

This quiet-refresh cycle continues until ~~PAM Tomlinson~~PAM16-~~Harashima precoded~~ THP signal at the beginning of a payload data sub-block slot is detected. The receive PHY exits LPI mode and returns to normal operation, sending the received payload to the GMII. The PCS decoding shall start aligned to the boundary of the first complete PDB received from the beginning of the payload data sub-block. At this moment, the local PHY begins to send normal-interframe encoding on the GMII, since this is the information received from the remote PHY and the link is ready to provide the nominal operational data rate.

114.5.4 1000BASE-~~RH~~ H PHY LPI mode timing parameters

Three key EEE parameters (T_s, T_q and T_r) are specified in Table 78–2 for a 1000BASE-H PHY.

The period of time that the PHY remains quiet before sending the refresh signal (pilot or physical header sub-blocks), denoted as T_q, corresponds to the transmission time of a payload data sub-block subtracting the time needed to transmit the sequences of zero symbols for quiet indication and for receiver preparation, which is given by

$\cancel{T_{payload}}\ T_q$ (μs) = (~~NCW * NSYM_CW –~~ NCW × NSYM_CW – NSYM_ZERO~~) /~~) / F_s = (~~8*~~8 × 988 - ~~160~~260)/325 = 23.~~83~~52 μs (114–1)

where NCW is the number of FEC codewords transmitted per payload data sub-block, NSYM_CW is the number of symbols composing a FEC codeword, NSYM_ZERO is the total number zero value symbols summing up those for quiet indication and receiver preparation, and F_s is the symbol frequency in MHz.

The duration of the refresh signal, denoted as T_r, corresponds to the transmission time of a pilot or physical header sub-block plus the time for quiet indication and receiver preparation, which is given by

$\cancel{T_{pilot/PHS}}\ T_r$ (μs) = (~~N SYM +~~ NSYM + NSYM_ZERO~~) /~~) / F_s = (16 + 128 + 16 + ~~160~~260)/325 = ~~0~~1.~~985~~30 μs (114–2)

where NSYM is the number of symbols composing a pilot or physical header sub-block~~.~~.

~~Additional LPI timing parameters for 1000BASE-H are specified in Table 78–4. Note that 24.82 μs is the time needed to transmit a pilot or physical header sub-block and a payload data sub-block.~~

Additional LPI timing parameters for 1000BASE-H are specified in Table 78–4. Note that 24.88 μs is the time needed to transmit a pilot or physical header sub-block plus a payload data sub-block plus the needed time to transmit 64 bits at the input of the MLCC demultiplexer. 64 bits is the worst-case offset of a PDB respect to the first bit of a payload data sub-block (see 114.2.4.1.1).

T_w (μs) = (NCW × NSYM_CW +NSYM +64/(1668/1976 × 2 + 1.5))/325 = 24.88 μs (114–3)

114.6 Interface to the PMD

The interface between the PCS and the PMD is defined in terms of signals for which no specific implementation is described.

114.6.1 Signals transmitted to the PMD

Any signal transmitted to the PMD by the PCS transmitter can be expressed in a general form independent of the different parts that compose the periodic Transmit Block (see 114.2.1) as follows.

$$\cancel{x(n) = SF(n)\cdot F_M\left(a(n) - \sum_{i_0}^{N_b} x(n-i-1)\cdot b(i)\right)}\ x(n) = SF(n)\cdot F_M\left(a(n) + \sum_{i=0}^{N_b-1} x(n-i-1)b(i)\right)$$

$$\cancel{= SF(n)\cdot\left(a(n) + 2M\cdot m(n) - \sum_{i-0}^{N_b} x(n-i-1)\cdot b(i)\right)}$$

$$= SF(n)\cdot\left(a(n) + 2M\cdot m(n) + \sum_{i=0}^{N_b-1} x(n-i-1)b(i)\right) \quad (114\text{–}4)$$

Where, $a(n)$ is an ~~M~~PAM-~~PAM-~~M modulation symbol that can take values from the set {-M~~+~~-1, -M+3~~,~~, ...~~.~~ +M~~-~~-3~~,~~ , +M-1} to be transmitted at time instants n·T_s, where T_s is the transmit symbol period (T_s = 1/F_s = 1000/325 ns), *SF(n)* is the power scaling factor specified for each part of the Transmit Block according to 114.2.1, *b(i)* are the coefficients of TH precoder specified in 114.2.4.5, and the nonlinear operation $F_M(\alpha) = mod(\alpha + M, 2M) - M$ corresponds to moving the ~~modulation symbol *a(n)*~~ signal $\alpha(n)$ to ~~an~~

115. Physical Medium Dependent (PMD) and baseband medium, type 1000BASE-~~RH~~ RH

115.1 Overview

This clause specifies the 1000BASE-RH PMD (including MDI) and baseband medium for plastic optical fiber. In order to form a complete Physical Layer, it shall be integrated with the 1000BASE-H PCS and PMA of Clause 114, and integrated with the management functions which are accessible through the MDIO Interface defined in Clause 45.

115.2 Physical Medium Dependent (PMD) sublayer service interface

The following specifies the services provided by the 1000BASE-RH PMD. The PMD sublayer service interface is described in an abstract manner and does not imply any particular implementation.

The PMD Service Interface supports the exchange of analog electrical signals between PCS entities. The PMD translates the electrical analog signals to and from optical signals suitable for the specified medium.

The following primitives are defined:

PMD_COMSIGNAL.request
PMD_COMSIGNAL.indication
PMD_TXPWR.request
PMD_RXPWR.request
PMD_RXDETECT.indication
PMD_SDINH.request

115.2.1 PMD_COMSIGNAL.request

This primitive defines the transfer of an analog signal amplitude from the PCS to the PMD.

115.2.1.1 Semantics of the primitive

PMD_COMSIGNAL.request(tx_signal).

During transmission, this primitive conveys to the PMD via the parameter tx_signal, the amplitude of the output signal to be produced by the PMD transmit function.

115.2.1.2 When generated

The PCS ~~transmit function~~ transmitter continuously generates PMD_COMSIGNAL.request(tx_signal).

115.2.1.3 Effect of receipt

Upon receipt of this primitive the PMD converts tx_signal into the MDI optical signal (see 115.3.3).

115.2.2 PMD_COMSIGNAL.indication

This primitive defines the transfer of an analog signal amplitude from the PMD to the PCS.

115.2.2.1 Semantics of the primitive

PMD_COMSIGNAL.indication(rx_signal).

This primitive conveys to the PCS via the parameter rx_signal the relative amplitude of the optical signal received by the PMD at the MDI. (see 115.3.4.)

115.2.2.2 When generated

The PMD_COMSIGNAL.indication(rx_signal) is continuously generated by the PMD in the form of an analog signal.

115.2.2.3 Effect of receipt

The effect of receipt of this primitive is unspecified.

115.2.3 PMD_TXPWR.request

~~This primitive is used for optional EEE capability. The primitive is generated to request the minimum PMD optical output power compatible with Low Power Idle (LPI) mode, or normal operation. When tx_pwr=OFF, the analog tx_signal is ignored.~~

This primitive is used for optional EEE capability. The primitive is generated to request no optical output power during quiet periods of LPI mode, or to request optical signal being generated at MDI during refresh periods of LPI mode or when normal-interframe operation of the PHY transmitter. When tx_pwr = OFF, the analog tx_signal is ignored.

115.2.3.1 Semantics of the primitive

PMD_TXPWR.request(tx_pwr).

The tx_pwr parameter can take one of the two values: ON or OFF

ON: The PMD Transmit function will generate signals at the MDI.

OFF: The PMD Transmit function will not generate signal at the MDI.

115.2.3.2 When generated

~~The PMD_TXPWR.request(tx_pwr) is generated during LPI mode to enable transmission of refresh signals and to reduce power consumption between such signals (see 114.5).~~

The PMD_TXPWR.request(tx_pwr) is continuously generated by the PCS transmitter and value depends on the operation mode as specified by the state diagram of Figure 114–46 (see 114.5).

115.2.3.3 Effect of receipt

PMD_TXPWR.request(OFF) requests the PMD transmit function to produce ~~the minimum~~ no optical output ~~power compatible with LPI mode~~ power, being the analog tx_signal ignored.

PMD_TXPWR.request(ON) requests the PMD transmit function to respond to PMD_COMSIGNAL.request primitives with generation of normal optical output.

115.2.4 PMD_RXPWR.request

This primitive is used for optional EEE capability. ~~-~~It is generated to request the PMD receive function to transition between being able to respond to received optical signals and a minimum power consumption state.

115.2.4.1 Semantics of the primitive

PMD_RXPWR.request(rx_pwr)

The rx_pwr parameter can take one of the two values: ON or OFF

ON: The PMD Receive function responds to receive MDI optical signals.

OFF: The PMD Receive function ignores receive MDI optical signals.

115.2.4.2 When generated

~~The PMD_RXPWR.request(rx_pwr) is generated during LPI mode to enable reception of refresh signals and to reduce power consumption between such signals (see 114.5).~~

The PMD_RXPWR.request(rx_pwr) is continuously generated by the PCS receiver and value depends on the operation mode as specified by the state diagram of Figure 114–47 (see 114.5).

115.2.4.3 Effect of receipt

PMD_RXPWR.request(OFF) requests the PMD receive function to ignore the receive MDI signal and reduce power consumption~~. It also forces the PMD_RXDETECT.indication(signal_detect) to latch the signal_detect value when signal_detect = OK (see 115.3.5)~~.

PMD_RXPWR.request(ON) requests the PMD receive function to respond to the received MDI signal.

115.2.5 PMD_RXDETECT.indication

This primitive is generated by the PMD receive function to indicate the status of the receive optical signal from the MDI.

115.2.5.1 Semantics of the service primitive

PMD_RXDETECT.indication(signal_detect)

The signal_detect parameter can take one of two values: OK or FAIL, indicating whether the PMD is detecting average optical power over a threshold (see 115.3.5) at the receiver (OK) or not (FAIL). When signal_detect = FAIL, then the rx_signal is undefined.

~~When rx_pwr = OFF, this primitive latches signal_detect value if signal_detect = OK, independently of optical signal level received at MDI. When rx_pwr = OFF is indicated while signal_detect = FAIL, it does not produce the signal_detect be latched.~~

When sd_inh = TRUE the signal detect function is inhibited and this primitive always provides signal_detect = OK, independently of optical signal level received at MDI.

NOTE—signal_detect = OK does not guarantee that rx_signal provides high enough quality to ~~be able~~ allow the PHY to establish the link. It just indicates that average optical power present at the MDI overpasses a threshold. It is possible for a poor quality link to provide sufficient average light power for a signal_detect = OK indication and still not meet the quality to establish the link with the BER ~~objective~~objective (see 114.1.1).

115.2.5.2 When generated

The PMD receive function generates this primitive to indicate a change in the value of signal_detect.

115.2.5.3 Effect of receipt

The effect of receipt of this primitive by the client is unspecified by the PMD sublayer~~,~~.

115.2.6 PMD_SDINH.request

This primitive is generated to request the PMD signal detect function to transition between being able to detect the received optical signals and an inhibition state.

115.2.6.1 Semantics of the service primitive

PMD_SDINH.request(sd_inh)

The sd_inh parameter can take one of the two values: TRUE or FALSE

TRUE: The PMD Signal detect function is inhibited.

FALSE: The PMD Signal detect function responds to receive MDI optical signals.

115.2.6.2 When generated

The PMD_SDINH.request(sd_inh) is continuously generated by the PCS receiver and value depends on the link status as specified by the state diagram of Figure 114–47 (see 114.5).

115.2.6.3 Effect of receipt

PMD_SDINH.request(FALSE) requests to PMD signal detect function to operate normally.

PMD_SDINH.request(TRUE) requests the PMD signal detect function to inhibit its functionality providing the primitive signal_detect = OK, independently of optical signal level received at MDI.

115.3 PMD functional specifications

115.3.1 PMD block diagram

For purpose of system conformance, the PMD sublayer is defined at the following points, depicted in Figure 115–2. The optical transmit signal is defined at the output end of 1 meter of plastic optical fiber consistent with the link type connected to the MDI. All the specified transmitter measurements are made at TP2. The optical receive signals are specified and measured at the output of the fiber optic cabling (TP3) which in a link is connected to the receiver.

TP1 and TP4 are standardized reference points for use by implementers to certify component conformance. The electrical specifications of the PMD service interface (TP1 and TP4) are not system compliance points of this standard (these are not readily testable in a system implementation). It is expected that TP1 and TP4 may be specified in other component specification documents for certain applications (e.g., automotive)~~.~~.

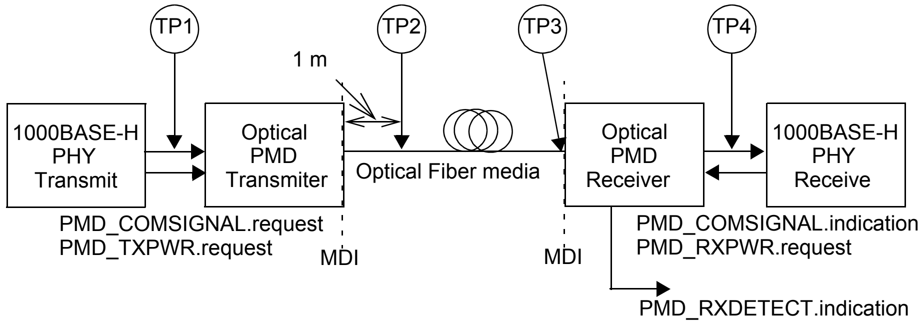

Figure 115–1—1000BASE-RH PHY block diagram

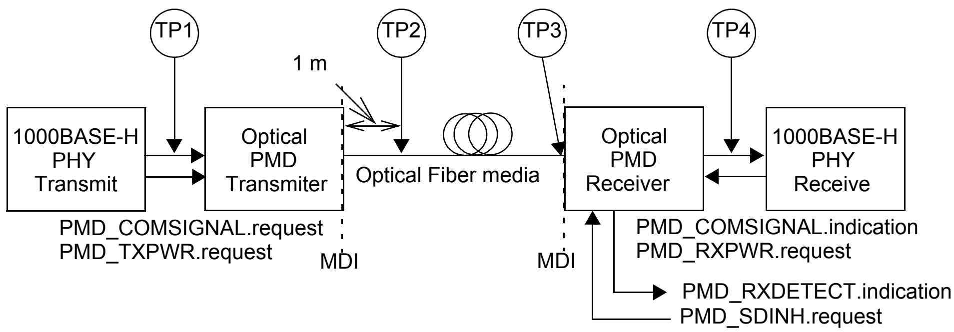

Figure 115–2—1000BASE-RH PHY block diagram

115.3.2 Link topologies

Six link types with application temperature environments and topologies are specified. Other applications and topologies may be possible within the available optical budget.

> ***Editor's Note (to be removed prior to publication):***
>
> *The below Table 115-1 has subtypes that only differ in temperature range requirements. This was done so that during WG ballot, reviewers will better see the option to adjust topology for each temperature range. If comments are accepted to change the topology for the different temperature range then the two subtypes will be required. If not, then the subtypes could be merged in Sponsor ballot.*

115.3.3 PMD transmit function

The PMD transmit function translates abstract PMD service primitives into optical ~~signals~~ signals. The transmit signal at the MDI is specified in 115.4.1.

The PMD transmit function shall translate the amplitude parameter tx_signal (see 115.2.1) into optical signal p at TP2 according to the following affine function:

Table 115–1—Specified link types

Type	Ambient Temperature Range	Topology
Type A	Consumer grade, 0° C — 70° C	50 m, 1 inline connection
Type B	Industrial grade, -40° C — 85° C	50 m, no inline connection
Type C1	Automotive grade, -40° C — 85° C	15 m, 4 inline connections
Type C2	Automotive grade, -40° C — 105° C	15 m, 4 inline connections
Type C3	Automotive grade, -40° C — 85° C	40 m, no inline connection
Type C4	Automotive grade, -40° C — 105° C	40 m, no inline connection

$$\cancel{p = \frac{p_1 - p_0}{2a}\text{tx\_signal} + \frac{p_1 + p_0}{2}}\; p = \frac{P_1 - P_0}{2a}\text{tx\_signal} + \frac{P_1 + P_0}{2} \qquad (115–1)$$

where, a is the maximum absolute value of tx_signal, and P_0 and P_1 are respectively the minimum and maximum optical power at TP2. The parameter a takes the value 256 and $a \le \text{tx\_signal} < a$ (see 114.6.1). Implementation of this affine function shall meet the specifications of rise time, fall time and harmonic distortion as specified in 115.4.1, per optical measurement requirements defined in 115.5.

PCS symbols take values from the interval [-256, 256). Symbols with the value -256 correspond to the minimum amplitude of tx_signal, and symbols with the value 256 correspond to the maximum amplitude of tx_signal. The zero symbols that are the prefix and postfix of pilots and headers are the value 0 and correspond to the average of the maximum and minimum amplitude of tx_signal.

The maximum amplitude of tx_signal shall be translated into the highest optical power (P_1) at TP2, the minimum amplitude of tx_signal shall be translated into the lowest optical power (P_0) at TP2. The average of the maximum and the minimum amplitude of tx_signal shall be translated to the average optical ~~launch~~ power (~~LOP~~AOP)~~.~~.

Extinction ratio (ER) in dB and ~~LOP~~ AOP in dBm are defined as:

$$ER = 10\log_{10}\left(\frac{P_1}{P_0}\right) \qquad (115–2)$$

$$\cancel{LOP = 10\log_{10}\left(\frac{P_1 + P_0}{2}\right)} \qquad (115–3)$$

$$AOP = 10\log_{10}\left(\frac{P_1 + P_0}{2}\right) \qquad (115–4)$$

where P_0 and P_1 are provided in mW. *ER* and ~~*LOP*~~ *AOP* shall meet the specifications for each topology defined in 115.4.1, per optical measurement requirements defined in 115.5.

Optionally, the PMD transmit function shall turn on and turn off the optical output as required by the PMD_TXPWR.request primitive. The transition times from receipt of this primitive until it takes effect at the MDI are specified in 115.4.1.

115.3.4 PMD receive function

The PMD receive function translates the optical signal received at the MDI into the analog signal amplitude provided by the abstract PMD_COMSIGNAL.indication(rx_signal) primitive. The receive signal at the MDI is specified in 115.4.2.

The PMD receive function responds to or ignores the receive MDI signal, during optional LPI mode, as requested by the PMD_RXPWR.request primitive. PMD_RXPWR.request(OFF) shall cause the PMD receive function to save the internal state of the circuitry to not be affected by the lack of received optical signal during a quiet period of LPI operation. The PMD receive function ignores the received MDI signal and reduces its power consumption. The PMD receive function saves state to be able to quickly restart translation of received MDI signal during the LPI mode refresh periods or when normal operation is resumed.

The PMD receive function shall respond to the MDI optical signal in response to receiving a PMD_RXPWR.request(ON). ~~-~~This allows the PMD to process the refresh signals in LPI mode and when normal operation of the PHY is resumed. The transition times from receipt of ~~this~~ PMD_RXPWR.request primitive until it takes effect in operation of the PMD receive function are specified in 115.4.2.

115.3.5 PMD signal detect function

The PMD Signal Detect function determines the value of the signal_detect parameter of the PMD_RXDETECT.indication PMD service interface primitive, which is signaled when the value of signal_detect changes.

The value of the signal_detect parameter shall be generated according to the conditions defined in Table 115–2, when sd_inh = FALSE. The PMD receiver is not required to verify whether a compliant 1000BASE-H signal is being received. This standard imposes no response time requirements on the generation of the signal_detect parameter.

Table 115–2—Signal detect value definitions

Receive conditions	Signal detect value
~~LOP~~ AOP at TP3 is < -35 dBm	FAIL
~~LOP~~ AOP at TP3 > -29 dBm	OK
All other conditions	See Figure 115–4

Implementation of the Signal Detect function shall generate the signal_detect parameter values in response to the average optical power present at the MDI~~.~~.

Figure 115–4 defines the PMD signal detect function. State variables are defined in 115.3.5.1~~.~~.

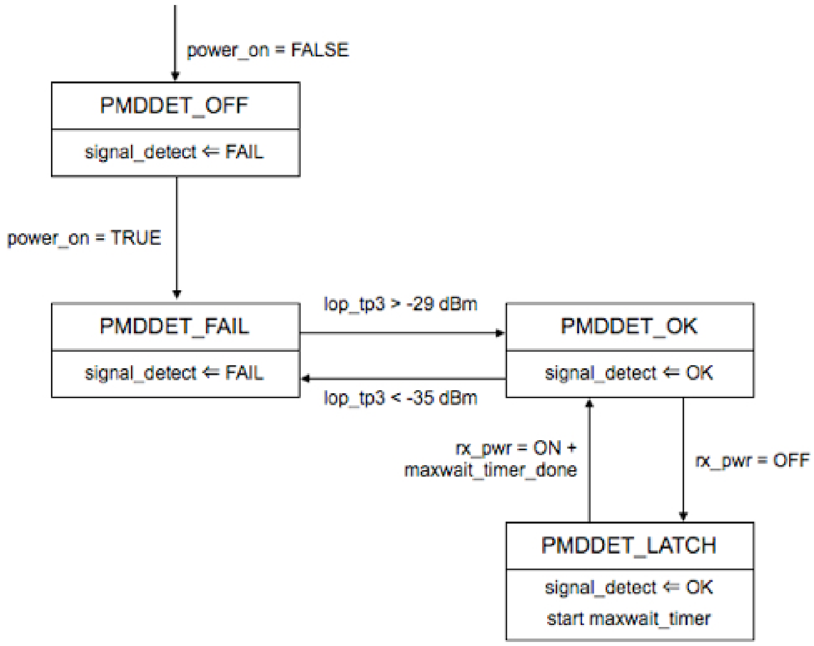

Figure 115–3—Signal detect state diagram

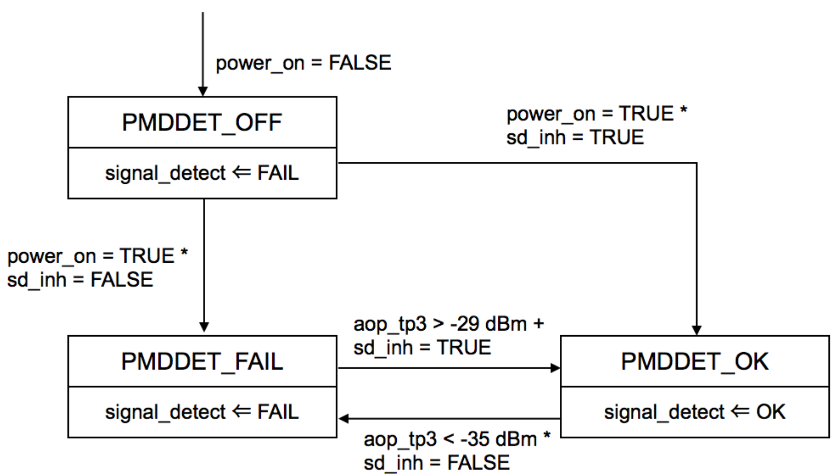

Figure 115–4—Signal detect state diagram

Upon PMD device power on (power_on ~~=~~= TRUE), the PMD signal detect function transitions to PMDDET_FAIL indicating signal_detect = FAIL if sd_inh = ~~FAIL~~FALSE, that indicates the functionality is not inhibited. When receive optical power at MDI is higher than a threshold of -29 dBm, the state diagram transitions to indicate signal_detect = OK (PMDDET_OK state). Once in this state, receive optical power at the MDI has to decrease below -35 dBm to cause transition to the PMDDET_FAIL state. These separated thresholds provide hysteresis in the signal_detect indication.

~~When in the PMDDET_OK state if rx_pwr = OFF is indicated, the signal_detect value is saved by the transition to PMDDET_LATCH state. This state is reached only when the complete 1000BASE-RH PHY has established a reliable link and the PMD is responding to PMD_RXPWR(OFF) to inhibit the PMD receive function during LPI mode quiet periods. Once rx_pwr = ON is received, a transition to PMDDET_OK is made, where the optical power is again evaluated against signal detect thresholds.~~

When sd_inh = TRUE, the PMD signal detect is inhibited, indicating signal_detect = OK in any case when power_on = TRUE.

115.3.5.1 PMD signal detect state variables

power_on
: Indicates the power state of the PMD. The state diagram takes the open-ended power_on = ~~OFF~~ FALSE branch.
: Values: ~~ON~~TRUE: power to PMD device is provided and circuit is operative.
: ~~OFF~~FALSE: the PMD is power off.

~~lop_tp3~~aop_tp3
: Indicates the average optical power received at the MDI, measured at the specification point TP3 per optical measurements defined in 115.5.4.

115.3.5.2 ~~PMD signal detect timers~~

~~maxwait_timer~~
: ~~A timer used to limit the amount of time during which a PMD receiver dwells in the PMDDET_LATCH state. The timer shall expire 50 µs ± 10 µs after being started. The timer is used in PMD signal detect state diagram.~~

115.4 PMD to MDI optical specifications for 1000BASE-RH

115.4.1 Transmitter optical specifications

A 1000BASE-RH transmitter shall meet the specifications at TP2 defined in Table 115–3 per measurement techniques defined in 115.5. It shall also meet the mode power distribution (MPD) defined in 115.5.9.

Table 115–3—1000BASE-RH transmit optical characteristics

Parameter	Symbol	Units	Value/Criteria	
			Min	Max
Average ~~launch~~ optical power	~~LOP~~AOP, type A	dBm	-6	1
	~~LOP~~AOP, type B		-7	1
	~~LOP~~AOP, types C1, C3		-7.5	1
	~~LOP~~AOP, types C2, C4		-9	1
Average ~~launch~~ optical power of OFF transmitter	~~LOP_{OFF}~~AOP_{OFF}	dBm		-35
Extinction ratio	ER	dB	11	

Table 115–3—1000BASE-RH transmit optical characteristics

Center wavelength	λ_c	nm	635	~~670~~665
Spectral width	λ_w	nm		20
Rise time (10% – 90%)	~~t_R~~t_r	ns		3
Fall time (10% – 90%)	~~t_F~~t_f	ns		3
Transmitter timing jitter	t_J	ps		20
2nd order harmonic distortion	HD_2	dBc[a]		-21
3rd order harmonic distortion	HD_3	dBc		-29
Relative intensity noise	RIN	dB/Hz		-137
~~Sleep~~ Off transition time (time from tx_pwr = OFF to ~~LOP_{OFF}~~AOP_{OFF})	~~t_{sleep}~~t_{off}	ns		~~TBD~~100
~~Wake~~ On transition time (time from tx_pwr = ON to ~~normal~~ active operation)	~~t_{wake}~~t_{on}	ns		~~TBD~~1500

[a]dBc (decibels relative to the carrier) figure is used to give the power ratio of an harmonic signal to a carrier signal, expressed in decibels. If the dBc figure is negative, then the harmonic signal strength is less than carrier signal strength.

Average optical power depends on the operation mode of the PHY transmitter (normal-interframe or LPI). AOP parameter is defined as the average optical power at TP2 when PMD transmit function receives primitive PMD_TXPWR.request(ON) (normal operation and LPI refresh signals). AOP_{OFF} parameter corresponds to the optical power when PMD transmit function receives primitive PMD_TXPWR.request(OFF) (LPI quiet periods). AOP_{OFF} maximum value is compatible with the PMD signal detect function specified in 115.3.5.

115.4.2 Receiver optical specifications

A 1000BASE-RH receiver shall meet the specifications at TP3 defined in Table 115–4 per measurement techniques defined in 115.5. It shall also meet the mode power distributions (MPD) defined in 115.5.9 for each link type.

Table 115–4—1000BASE-RH receive optical characteristics

Parameter	Symbol	Units	Value/Criteria	
			Min	Max

Table 115–4—1000BASE-RH receive optical characteristics

Average optical ~~receiver input~~ power	~~LOP~~AOP, type A	dBm	-17	1
	~~LOP~~AOP, type B		-17	1
	~~LOP~~AOP, type C1		-18.5	1
	~~LOP~~AOP, type C2		-18.5	1
	~~LOP~~AOP, type C3		-17	1
	~~LOP~~AOP, type C4		-17	1
~~Quiet~~ Off transition time (time from rx_pwr = OFF to ~~LPI quiet~~quiet mode)	~~t_{quiet}~~t_{off}	ns		~~TBD~~200
~~Wake~~ On transition time (time from rx_pwr = ON to active operation)	~~t_{wake}~~t_{on}	ns		~~TBD~~400

The sensitivity is defined as the minimum value of ~~LOP~~ AOP at TP3. It is assumed that a 1000BASE-RH PMD is not tested standalone, but is always considered as part of a complete Physical Layer (i.e. 1000BASE-H PCS and PMA sublayers are also included). Therefore, a complete 1000BASE-RH Physical Layer shall be able to establish a reliable link throughout the average optical power (~~LOP~~AOP) range between the minimum and maximum defined in Table 115–4.

115.4.3 Worst-case 1000BASE-RH link power budget and penalties (informative)

The worst-case link power budget and link margin for the 1000BASE-RH channels defined in Table 115–5, are based on the transmitter and the receiver optical specifications provided in 115.4.1 and 115.4.2, respectively.

Table 115–5—1000BASE-RH link power budget and link margin

Parameter	Type A	Type B	Type C1	Type C2	Type C3	Type C4
Link length (m)	50	50	15	15	40	40
Number of inline connections	1	0	4	4	0	0
Min ~~LOP~~ AOP at TP2 (dBm)	-6	-7	-7.5	-9	-7.5	-9
Plastic optical fiber max attenuation (dB)	9.5	10	3	3	8	8
Max insertion loss due to inline connections (dB)	1.5	0	6	6	0	0
Sensitivity at TP3 (dBm)	-17	-17	-18.5	-18.5	-17	-17
Link margin (dB)	0	0	2	0.5	1.5	0
Link power budget (dB)	11	10	11	9.5	9.5	8

115.5 Optical measurement requirements

All the optical measurements of the transmitter shall be made at TP2 (at the end of a 1m length of POF cable consistent with the link type). The optical measurements in the receiver shall be done at TP3.